Si

NATURAL

RESOURCES

RESEARCH

INSTITUT

THE LIBRARY OF THE
JAN 9 1963
UNIVERSITY OF ILLINOIS

University of Wyoming

Laramie, Wyoming

333.7
W98
1949/50

TABLE OF CONTENTS

ABSTRACT – Summary the Year in Review. 2,3,4

EXECUTIVE COMMITTEE & STAFF 5

GENERAL PROGRESS 6

PUBLICATIONS 7

PATENT 7

TALKS 8

SPECIAL STAFF ACTIVITIES 9,10,11

MAJOR PROJECTS

Coal 12,13,14,15

Phosphoric Acid & Phosphate Fertilizer . . 16,17,18

Iron Ore Deposits, near Atlantic City 18

MISCELLANEOUS ACTIVITIES

Portland Cement 19

Titanium Alloy 19

Concrete Aggregate Research 19

Assay and Analytical Service 19

FUTURE PLANS 20,21

ABSTRACT

Summary: The Year in Review

During the year 1949-50 the N.R.R.I. program on resource development has effectively "paid off", through the activity of industrial concerns in Wyoming, through publications issued and about to be released, and through requests for information on undeveloped resources.

Coal

The basic Institute coal research program, greatly strengthened through the now completed U. S. Department of Commerce project, has been continued in cooperation with the Bureau of Mines and broadened in scope. This increase in coal research activity has been possible through the 1950-51 legislative appropriation for coal work at N.R.R.I. The briquetting facilities at the Institute have been employed for additional E. C. A. work on Greek lignites in cooperation with the Bureau of Mines, and testing facilities have been made available to other interests.

A grant in the amount of $1,200.00 was received by the N.R.R.I. to conduct a project sponsored by the Hoberg Paper Mills; Appleton, Wisconsin, for an investigation of four spent sulphite liquors as binders for coal briquets.

Plans have recently been formulated to introduce a sampling and analysis service for the Wyoming coal industry to be started in a modest way during the coming year, and this work has been staffed.

The Wyoming coal resources map in preparation during the past year has been substantially completed and text material to accompany the map is in preparation. The bulletin and map should be in press before January 1, 1951.

Following the program outlined a year ago, work on drying and briquetting has been continued, and a fluo-solids drier, following design data developed by Mr. V. F. Parry at Golden, is being installed in conjunction with the existing briquetting facilities.

Phosphate Deposits

The first major project undertaken by the Institute shortly after it got under way, was an investigation of intermediate grade phosphate deposits of the Wind River Mountains near Lander. Leasing of certain tracts in the area by a Texas group with the object of commerical fertilizer production in Central Wyoming brings to a successful culmination the first phase of the Institute's activity in favor of these deposits. It also evidences the results of cooperative action between the various private and governmental agencies which have worked together on this project. Important problems on up-grading the rock and economically processing it for concentrated superphosphate production still remain, but with the necessary support enabling increase in "man power" on the work, it is confidently expected that these problems will rapidly be solved through completion of work now in progress. Commercial development will be based on bringing together two Wyoming resources - sulfur from the Sunlight Basin and phosphate rock from the Lander deposits, a direct result of the Institute's activity in study and coordinative development of Wyoming resources.

Petroleum

In last year's annual report it was pointed out that in volume of business activity the petroleum industry is the most important resource enterprise in the state. Several problems peculiar to the local industry were mentioned. Through adjustment of budget and plans now completed, it will be possible to initiate a fundamental research project on sulfur removal from black oils, starting July 1, 1950, and arrangements to staff this work

have been made . The Curran Carbonizing and Engineering Company of Saint Louis has offered cooperation in this research program.

Undeveloped Resources

Through the financial support of the Chicago and Northwestern Railway System, enabling the engagement of Mr. Ralph H. King as consulting geologist last summer, field and laboratory investigations were made upon iron ore shists near Atlantic City and on Portland cement raw material resources in Central and East Central Wyoming. In connection with the latter, a small sample of Portland cement clinker was prepared from the cement raw materials obtained by Mr. King in the field, and from this clinker a Portland cement with normal characteristics was made. Results of both of these investigations have furnished information to concerns interested in commercial possibilities of these resources.

Fundamental Research

Since results of the purely scientific or basic research of today produce the building blocks of data, information and knowledge for the applied or technological research of tomorrow, it is vital that in any well balanced research program some fundamental research be carried on along with applied research activities. In line with this philosophy, a limited amount of fundamental research directed toward deriving information on the constitution of western coals has been in progress during the past year. This work takes the form of a doctoral research project in the chemistry department carried on in the N.R.R. laboratories as a graduate fellowship through the graduate school. The cooperation of the Chemistry Department of Purdue University has been essential in this particular investigation and is gratefully acknowledged.

EXECUTIVE COMMITTEE

H. T. Person, Chairman
G. D. Humphrey
H. D. Thomas
A. J. McGaw
H. G. Fisk, Secretary

Staff Members

H. G. Fisk	Director
Charles C. Boley	Coal Research Engineer
Neal Rice	Coal Research Chemist
Walter E. Duncan	Chemical Engineer
Bahngrell W. Brown	Chemist
Celia Bollich (Mrs.)	Coal Project Assistant
Thomas Arsulich	Coal Engineer
Rosalie Reynolds (Mrs.)	Asst. to Chemical Engineer
Fred James	Pilot Plant Assistant
Carl Huetting	Mechanician
Helen Hare	Secretary
June Whipple	Clerk-Typist

Assistants

George Balog	Student Assistant
Harold Brown	Student Assistant
Darreld Barnes	Student Assistant
Delbert Robinson	Student Assistant
Rupert Rock	Student Assistant
K. Y. Hing	Student Assistant

GENERAL PROGRESS

The coal research program has been materially strengthened and broadened through the special legislative appropriation of $45,875.00 for continued coal work at the N.R.R.I. for the 1950-51 biennium. This has enabled the coal research staff to be maintained at four full time persons with student assistants. Mrs. Celia Bollich became project assistant on the Hoberg Paper Mills contract, in April, 1950.

In August, 1949, Mr. Walter E. Duncan assumed the duties of chemical engineer and has since directed his main efforts toward the technical and economic problems in connection with the Lander phosphate project.

The basic equipment of the Institute has been increased in all branches. The coal flash (fluo-solids) drying plant has been practically completed, flotation equipment has been added in the minerals laboratory and a glass blowing lathe acquired from surplus property has been put into operation.

The new office building fronting on Lewis Street is under construction and plans have been drawn for remodeling the present office rooms into laboratories.

Assistance of the Torrington Agricultural Substation, through Mr. W. L. Quayle for the field testing of Rhenanian phosphate produced in the pilot plant, has been continued.

The cooperative relationship between the Institute and the Bureau of Mines in coal technology has been continued.

PUBLICATIONS

Bulletin No. 3, Briquetting of Dried Low-Rank Western Coals, Boley, Charles C. and Rice, Neal.

Information Circular No. 3, Proceedings of a Coal Briquetting Conference, ($1.00 per copy).

Miscellaneous Publication No. 3, Wyoming's Natural Resources, (Mimeographed).

Miscellaneous Publication No. 4, Summary Facts on Wyoming Coal Resources, (Available on request).

Miscellaneous Publication No. 5, The Volatile Matter Determination of Certain Ebulent Coal Chars, Rice, Neal; Brown, B. W.; and Balog, George, Abstract in J. Colorado-Wyoming Academy Science 4 (1) P. 18, November 1949.

Miscellaneous Publication No. 6, Improving the Weathering Characteristics of Subbituminous Coals by Drying and Briquetting, Boley, Charles C. and Rice, Neal. Abstract in J. Colorado-Wyoming Academy Science 4 (1) p.32, November 1949.

Reprint No. 9, A Study of the Effect of NaCMC on Bentonite, by Brown, Bahngrell W, World Oil, September 1949.

*Miscellaneous Publication No. 7, Iron Deposits Near Atlantic City, King, Ralph H. (Mimeographed).

*Miscellaneous Publication No. 8, Portland Cement Materials of Central and East Central Wyoming, King, Ralph H. (Available on request).

*Miscellaneous Publication No. 9, Pilot Plant Production Fused Defluorinated Phosphate Rock, Fisk, H. G. (Available on request).

*Cooperative investigation - Chicago and Northwestern Railway System.

PATENT

Patent "Refractory and Process of Making Same" by H. G. Fisk has been allowed by the U. S. Patent Office with ten claims and will be issued with assignment to the University.

TALKS

September 21, 1949, P. T. Miller presented a paper, By-Product Pectin from Sugar Beets, at the annual meeting of the American Chemical Society in Atlantic City.

November 15, 1949, the director spoke before the College of Education faculty on Wyoming's resources.

January 11, 1950, the director spoke to the Laramie Optimists Club on Why Develop Wyoming's Resources?

January 11, 1950, Charles C. Boley spoke to the Reserve Officers Unit, Laramie, on Coal Technology.

January 12, 1950, Charles C. Boley spoke to the Reserve Officers Unit, Cheyenne, on Coal Technology.

January 24, 1950, Charles C. Boley spoke to the Ceratopsians Club on the campus on Coal Technology.

April 25, 1950, the director presented a paper, New High Lime Refractory Resistant to Phosphate Melts, at the annual convention of the American Ceramic Society in New York.

May 10, 1950, Walter E. Duncan spoke to the student section ASME and Sigma Tau on Submerged Combustion.

May 12, 1950, the director presented a paper, Processing Intermediate Grade Wyoming Phosphate Rock, before the engineering section, Colorado-Wyoming Academy of Science, co-authored with Walter E. Duncan.

May 12, 1950, Walter E. Duncan presented a paper, Submerged Combustion, to the engineering section of the Colorado-Wyoming Academy of Science.

SPECIAL STAFF ACTIVITIES

July 14, 1949	Charles C. Boley attended a meeting of the National Bituminous Coal Advisory Board in Denver.
August 3, 1949	Charles C. Boley attended a regional meeting of the National Coal Association in Denver.
August 12-14, 1949	The director met with General Sulphur Company officials at Cody and visited their properties in the Sunlight Basin.
September 1, 1949	The director and W. E. Duncan accompanied representatives of the General Sulphur Company on a field trip to the Lander phosphate deposits. This group has since leased the deposits with the purpose in view of a commercial operation.
September 30-October 1, 1949	Senior members of the Institute staff attended technical sessions at the School of Mines 75th anniversary in Golden.
October 15, 1949	W. E. Duncan accompanied a representative of a Chicago contracting firm to Lander to inspect the phosphate deposits.
October 20, 1949	W. E. Duncan conferred with officials of Monsanto Chemica Company in St. Louis.
October 24, 1949	B. W. Brown visited mining claims on Sheep Mountain and collected samples for assay.
October 31-November 1, 1949	The director visited Lander in the company of private interests seeking information on Wyoming resources.
November 4, 1949	The director represented the Institute at a conference on dried lignite, sponsored by the Bureau of Mines and the University of North Dakota at Grand Forks. A special report was prepared on this conference.
November 25-26, 1949	The Institute was represented at the fall A.I.M.E. meetin in conjunction with the Wyoming Geological Association meeting in Casper.
December 2, 1949	Through the courtesy of Mr. B. M. Snell, the director was a guest at the Third Annual American Men of Science and Industry dinner in Washington, D. C. While in Washington officials of the U. S. Department of Commerce and also Senator Joseph C. O'Mahoney were visited.

December 10, 1949	A group from the Institute attended the winter meeting of the Wyoming section A.I.M.E. at Rock Springs.
February 3-4, 1950	The director and B. W. Brown attended the Colorado Mining Association meeting in Denver.
February 9-11, 1950	The director and B. W. Brown accompanied Mr. Frank Osterwald, assistant state geologist to Lusk to visit the abandoned Cliff mine and other locations where radio-active minerals are reported.
March 2-3, 1950	The director and W. E. Duncan conferred at Dallas with the Texas group which was the successful bidder on the Lander phosphate leases.
March 22-24, 1950	The director visited sulfur plants of the Stanolind Oil and Gas Company at Elk Basin, and also the Texas Gulf Sulphur Company at Worland.
April 8, 1950	The director accompanied Dr. W. G. Solheim to Boulder, Colorado to attend a meeting of the Board of Trustees of the Colorado Wyoming Academy Research Foundation.
April 12-15, 1950	W. E. Duncan visited the phosphate fertilizer plant of the Anaconda Mining Company at Anaconda, Montana.
April 24-May 2, 1950	The director and W. E. Duncan made various contacts in the east in connection with the research program of the Institute.
May 12, 1950	Charles C. Boley acted as chairman of an engineering section meeting of the Colorado-Wyoming Academy of Science meeting at Fort Collins.
May 12, 1950	B. W. Brown presented a paper, Clay topo-chemistry: Notes on Nickel Dimethylglyoximate to the Chemistry Section, Colorado-Wyoming Academy of Science.
May 12, 1950	Raymond F. Stevens presented a paper, The Chromotography of Coal Extracts II. Report of Progress to the Chemistry Section of the Colorado-Wyoming Academy of Science.
May 12, 1950	W. E. Duncan presented a paper, Submerged Combustion, to the Engineering Section of the Colorado-Wyoming Academy of Science.
May 12, 1950	The director presented a joint paper with W. E. Duncan, Processing Intermediate Grade Wyoming Phosphate Rock, to the Engineering Section of the Colorado-Wyoming Academy of Science.
May 13, 1950	N.R.R.I. arranged a program and acted as host to the Wyoming section of A.I.M.E.

May 13, 1950	Neal Rice represented the Institute at a conference on drying lignite sponsored by the Minnesota-North Dakota Resources Development Commission at Grand Forks. A special report was prepared on this conference.
June 10, 1950	The director visited the electric furnace phosphorus plant of the Vestvaco division of the Food Machinery and Chemical Company at Pocatello, Idaho, also the phosphate mine of the Simplot Fertilizer Company on the Ft. Hall Indian Reservation. Both of these visits were made possible through the courtesy of Mr. George A. McHugh, Manager of Mines, Simplot Fertilizer Company.
June 14, 1950	The director conferred with Mr. Carl Stehle, Jr., of the Vaca Oil Exploration Company at Oxnard, California, in connection with contemplated N.R.R.I. oil research activities.
June 19-21, 1950	Mr. Neal Rice and Mr. Tom Arsulich represented the Institute at the forty-sixth meeting of the Rocky Mountain Coal Mining Institute at Glenwood Springs, Colorado.

MAJOR PROJECTS

Coal

Prior to the first of the fiscal year, a final report had been submitted to the Office of Technical Services, United States Department of Commerce, covering all completed phases of the project which that office had cooperated in sponsoring. An uncompleted phase, however, consisted of 14 combustion tests in the stove assembly, and the above-mentioned final report was submitted in typewritten form with the understanding that all testing phases be completed and the report be reworked to include them before printing. Accordingly, combustion tests proceeded, and as of the first of the fiscal year, the laboratory part of three had been done. During July and August, the laboratory part of the balance of the tests was accomplished, including two re-runs.

Recognizing the importance of economic considerations in briquetting, much care was given to the treatment of this topic. The section on economics, as originally submitted in typewritten form, was sent to 15 or 20 well-informed men for critical comment, and a questionnaire on costs was prepared and sent to all known operators in the United States and Canada. On the basis of informatio obtained in these and other ways, the section was entirely re-worked. At the same time, calculations were completed on the combustion tests, and the sections on results and conclusions were re-written, with the preparation of revised graphic material. Other sections of the original typewritten report were also recast as necessary.

In connection with the construction of improved coal drying facilities to be integrated with the briquetting plant, conferences with United States Bureau of Mines officials in Denver began in November, and design and construction work has proceeded to the point that all major units have been fabricated and installed, at the present date. Instrumentation and certain interior work on the dry-coal receiver are the major uncompleted phases.

All available sources of information have been consulted, and the drafting work is substantially complete for a map of the state, scale of 1/500,000, in two colors, showing coal areas, areas that have been covered by previous field studies, and all known coal mines. Work on the accompanying text, which will summarize and analyze all authentic information on the coal fields of the state, has been started.

During the period under review, the second and third phases of cooperative testing with the United States Bureau of Mines on Greek lignite were completed, and eight copies of a report on each phase were forwarded to the Bureau. The second phase of the work involved the briquetting of a quantity of lignite char, carbonized by the Disco Corporation of Pittsburgh, and the testing of the brique the third phase was the testing of high pressure, binderless briquets made of dried lignite by Komarek-Greaves and Company in Chicago.

An evaluation of four sulphite liquors (a waste product of paper mills) was undertaken for the Hoberg Paper Mills of Green Bay, Wisconsin, on March 1, the work to be completed and reported by August 1. A coal blend closely simulating Great Lakes dock fines was prepared, upon which all work is based. Exploratory work has fixed a desirable range of sulphite liquor and asphalt emulsions, and most of the necessary small-scale runs have been made. Two progress reports hav been submitted to Hoberg Paper Mills.

Combustion tests were made on one sample of coal and one of briquets for th Kananaskis Exploration and Development Company of Nordegg, Alberta, and a third combustion test is to be undertaken in June. By the end of the fiscal year a re port will have been submitted on the data and conclusions of this study.

The final text of Bulletin 3, Briquetting of Dried Low-rank Western Coals, was edited for accuracy and style, cuts were designed and prepared, and other necessary steps taken to result in the printing of an edition of 1000 copies. Distribution was effected to the United States Department of Commerce, the Unite

States Bureau of Mines, all domestic and foreign libraries with which the University of Wyoming has exchange agreements, and various interested technical organizations and individuals. At the present time 177 copies are still on hand.

Following the briquetting conference of June 24 and 25, 1949, the text and ensuing discussion for each of the 13 technical papers were assembled and edited into a complete volume of proceedings, and an initial printing of 215 copies was produced. A charge of $1.00 per copy was established, and the printing was exhausted in approximately two months. A second printing of 25 copies and a third of 50 copies were later prepared, and at present 32 copies are on hand.

During the immediate future the drying plant will be completed and placed in operation, and data on high-speed, dust free drying of high-moisture fines wil be assembled. An important aspect of this work will be the design of equipment for controlled cooling of hot dry coal fines, either to briquetting temperature (about 150° F) or for a safe temperature for storing and handling. When dry coa can be produced under predictable and controllable conditions, integrated operat of drying and briquetting will be demonstrated, and cooperation will be arranged with industrial coal users to permit study of the utilization characteristics of the coal.

In order to more effectively serve the Wyoming coal industry it has been decided to activate a sampling and analytical program. Since the Bureau of Mine suspended this type of work in 1947 in the Western States, there has been a need for this service by a disinterested agency qualified to carry it on. Sampling and analytical work under the proposed program will be conducted in strict accor ance with Bureau of Mines and American Society for Testing Materials procedures. Analyses made will consist of proximate items, sulfur, heating value, and ash fusion temperature, and the results will be reported without charge to the owners or operators of the mines sampled. If the mine owner wishes, the analytical data will be held confidential for a period of one year following date of reporting.

Mr. Thomas Arsulich, a mechanical engineer with experience in coal, has been engaged for the program, which will begin about October 1. Mr. Arsulich will be equipped with a portable crusher and accessories and will be prepared to sample all coal sizes produced at mines desiring the service that can be visited during the two months of field work to which available funds restrict the activity during the fiscal year ending June 30, 1951.

In the field of fundamental coal research a project on the constitution of coal has been in progress. The ultimate understanding of coal chemistry would b aided by a definite knowledge of the chemical structure of the substance. The aims of this work are to isolate and identify the compounds present in a bituminous and a subbituminous coal. If mild methods of treatment are employed these compounds may be valuable evidence as to the chemical structure of the coal material.

To increase the solubility of the coal substance, low temperature chlorination has been adopted. A cooperative agreement between Purdue University and the Natural Resources Research Institute and Department of Chemistry of the University of Wyoming was negotiated. Under this agreement samples of two Wyoming coals were taken to Purdue for treatment. After some preliminary work to determine methods and conditions, these coals were chlorinated using the laboratories, equipment, and materials that were made available there. The processing resulted in a three to five fold increase in solubility of the products over that shown by the corresponding raw coal.

Solvent extractions of both the raw and chlorinated coals are being carried out in the laboratories at Laramie. From the chlorinated subbituminous coal one compound has been isolated, analyzed, and X-ray data obtained. Further work wil be needed to show the identity of this material.

During the coming year, extraction and isolation work will be continued on the raw and chlorinated coals to obtain other compounds that may be present in

the raw coal or may have been produced by chlorination. Identification work on compounds will be attempted. Further work on coal compounds will be done as needed to determine their significance in coal chemistry.

Phosphoric Acid and Phosphate Fertilizer

Preliminary economic evaluation of the problem of producing phosphate fertilizer materials from the phosphate rock in the Wind River Area (Lander) has pointed out that success must be achieved on one or both of two phases of the problem in order to support an economically sound manufacturing operation. These two important adjuncts are (1) the production of cheap sulfuric acid and (2) the beneficiation of the rock, particularly as regards the calcium carbonate content.

It is recognized that any beneficiation procedure is going to cost money and that it will be necessary to have data available to permit evaluation of the achievements. Consequently, the entire problem has been divided into two categories: (1) Production of phosphoric acid and concentrated superphosphate employing the rock as available in the area, and (2) Beneficiation of the rock as regards removal of the undesirable impurities which occur with it. Almost no work has been done regarding the production of cheap sulfuric acid.

Some small acale equipment has been set up to study the production of wet process phosphoric acid from Wyoming rock, so as to establish the operating variables which are involved. This work has not progressed to a point where any real data are available, but is being carried along with prime attention being paid to the beneficiation aspects.

Under an agreement with Phosphate Mines, Incorporated, of Kemmerer, Wyoming, a continuous test was conducted in which about three tons of Rhenania-type fertilizer were prepared by reacting Wyoming trona with phosphate rock from the company's mines. This test, which was run continuously over a period of three

days, was made in the three-foot diameter by twenty-foot long, gas fired, kiln in the pilot plant and was designed to study the effect of ratio of trona to phosphate rock on the available phosphate content of the product under various temperatures of operation. In the test it was found that about 80-90% of the P_2O_5 was converted to available (A.O.A.C. citric acid soluble) phosphate in the presence of a 50% excess of trona over the quantity required to produce the compound $CaNaPO_4$.

The temperatures employed varied from 1600-1900° F and under these condition there was no apparent attack on the magnesite living in the hot end of the kiln although the product was very close to, and sometimes above, the fusion temperature as it discharged from the kiln.

About 1000 pounds of a product comparable to superphosphate in available P_2O_5 analysis has been ground in a ball mill and samples were furnished the University of Wyoming Agricultural Experiment Station and the Texas Research Foundation for field tests.

A comprehensive bibliography on phosphate has been started.

A great deal of time has been spent in the accumulation and evaluation of fundamental data as regards the physical make-up of the raw phosphate rock involved. These data have been obtained by means of heavy liquid separation at various specific gravities so as to indicate the degree to which crushing and grinding have liberated the several mineral entities present. It is readily seen that if the minerals are not freed in such crushing so as to produce particles made up only of a single mineral, it will not be possible to make a physical separation of any consequence.

The data are now rather complete and there are indications that the liberati on crushing of the rock is rather incomplete. About half of the excess limestone is freed by crushing in the 100-mesh range with greater or less liberation in the finer and coarser sizes respectively. Liberation as regards insoluble impurities,

such as quartz, is about 80% completed in the 100-mesh range. These latter impurities are of less consequence in that they do not represent very much in the way of increased processing costs since they are not acid-consuming entities as is the limestone. Moreover, there are established procedures for the separation of quartz from phosphate rock while the separation of limestone from phosphate is not known.

One procedure which preliminary testing has indicated to be promising is calcining the rock to convert the limestone to quick lime. Subsequent hydration or slacking, will cause it to disintegrate to a powder which can be readily removed from the balance of the rock. This procedure is being thoroughly studied from the standpoint of calcination temperature and condition, slacking condition and subsequent separation of the hydrated lime. Preliminary data indicate that about 40% of the lime can be rejected while recovering over 80% of the original phosphate mineral and every effort will be made to establish conditions which will improve these preliminary results.

Iron Ore Deposits Near Atlantic City

During the summer of 1949, through the financial support of the Chicago and Northwestern Railway System, Mr. Ralph H. King, consulting geologist, assisted b Mr. Glen Faulkner, mapped and sampled outcropings of iron ore schists occurring between Rock Creek and Beaver Creek near the Lander-Rock Springs highway south o Lander.

Chemical analyses and microscopic examinations of these samples were made by the N.R.R.I. The ore was found to average 35.18% Fe and Mr. King estimated a reserve of 73,000,000 tons in the area mapped. This figure is conservative as i is known that a large potential tonnage of ore was not mapped. The ore was foun to consist of magnetite partially altered to hematite (martite) with a siliceous gangue predominately quartz. As the magnetite (magnetic) and hematite are intimately associated, it is thought that the iron ore can be beneficiated by

333.7
W98
1952/53

NINTH ANNUAL REPORT

July, 1953

NATURAL
RESOURCES
RESEARCH
INSTITUTE

THE LIBRARY OF THE
JAN 9 1963
UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING

The University of Wyoming

Laramie, Wyoming

NINTH ANNUAL REPORT

July, 1953

NATURAL RESOURCES RESEARCH INSTITUTE

COLLEGE OF ENGINEERING

The University of Wyoming

Laramie, Wyoming

333.7
W99e
1952/55

The Natural Resources Research Institute was organized as a department of the University of Wyoming following an appropriation by the State Legislature for its establishment in 1943, and in 1949 became the Engineering Experiment Station of the University.

The object of the Institute is to aid in the development of the natural resources of the State and to promote its industrial growth and the wider utilization of the minerals, fuels, and other resources through laboratory investigations and research upon these resources. The research carried on by the Institute is therefore concerned primarily with problems relating to production, beneficiation, processing, and application of the State's resources for industrial or consumer uses.

Although the Institute maintains completely equipped laboratories and a full-time staff, the research facilities of the University proper are available to the Research Institute, as are the services of University faculty members in a consulting and advisory capacity.

The Institute cooperates fully with other state, federal, and private agencies in the solution of problems of a scientific or industrial nature and may enter into contractual arrangements with corporations or individuals to carry on sponsored investigations or researches, particularly those that may be of possible future benefit to the State.

TABLE OF CONTENTS

Page

EXECUTIVE COMMITTEE AND STAFF - - - - - - - - - - - - - 1

SUMMARY - 2

COAL RESEARCH - 6

PHOSPHATE RESEARCH - - - - - - - - - - - - - - - - - - 10

PETROLEUM RESEARCH - - - - - - - - - - - - - - - - - - 13

SULPHITE PROJECT - - - - - - - - - - - - - - - - - - - 15

ORDNANCE PROJECT - - - - - - - - - - - - - - - - - - - 17

MISCELLANEOUS - 17

FUTURE PLANS - 18

SPECIAL STAFF ACTIVITIES - - - - - - - - - - - - - - - 21

COMMITTEE ASSIGNMENTS - - - - - - - - - - - - - - - - 23

EXECUTIVE COMMITTEE

H. T. Person, Chairman
G. D. Humphrey, Ex Officio
H. D. Thomas
A. J. McGaw
R. A. Morgan
H. G. Fisk, Secretary

SENIOR STAFF

Henry G. Fisk - Director

Walter E. Duncan - - - - - - - - - - - - - - - - - - Chemical Engineer

Neal Rice - Coal Research Chemist

Edward Prostel - - - - - - - - - - - - - - - - Coal Research Engineer

Ralph D. Law - - - - - - - - - - - - - - - - - - - Petroleum Chemist

Raymond F. Stevens - Chemist

Robert L. Eichelberger - - - - - - - - - - - - - - - - Project Chemist

Oren Franklin Neal - - - - - - - - - - - - - - - - - - - Mechanician

Louanne Erickson (Mrs.) - - - - - - - - - - - - - - - - - Secretary

Rachel Puntriano (Mrs.) --- - - - - - - - - - - - - - Project Assistant

Donna Clausen - Clerk-Typist

John R. Boles - - - - - - - - - - - - - - - - - - Laboratory Assistant

Walter W. Moore - Assistant

STUDENT ASSISTANTS

David Bagley
Donald Lee Bender
Gerold M. Brookshire
Alexander Chocas
Charles T. Conley
Delano Dinelly
Charles Ferrin
Joseph M. Fillerup
Paul E. Frazier
Roger Hubbell
Donald Larsen
John J. McIntyre
Edward S. McKinney
Charles C. Messer
Bill Phillips
Kenneth R. Porter
Robert K. Rasmussen
Roger J. Rasmussen
Selmer Pederson
Thomas M. Schwarberg, Jr.
Naim S. Turk

SUMMARY

Work on the processing of Wyoming phosphate rock has been concentrated principally on defluorination and solubilization of the rock in the rotary kiln. It has been found that substantial defluorination can be accomplished by high temperature treatment either with or without melting. Control of composition by suitable additions is necessary and the correct compositional adjustment has to be worked out for each type of rock to be processed. It is possible to attain a degree of defluorination deemed sufficient to produce a satisfactory feed supplement without melting providing the lime silica ratio in the rock is properly adjusted. However, to maintain the higher phosphorus content in the product complete melting is necessary, and to attain complete melting, the high lime refractory developed at the Institute (U. S. patent 2,528,471) seems necessary as a refractory lining in contact with molten phosphate rock. Further development of the refractory is in progress, both on the fundamental aspects - under the Ordnance project as well as the applied phases in the pilot plant.

Beneficiation of the intermediate grade Central Wyoming phosphate rock by thermal treatment has not met with the anticipated success, seemingly due to an affinity between calcium oxide released on calcination, and other constituent or constituents in the rock. The mechanism of this reaction offers a challenging problem for basic research in inorganic chemistry, and would make a good graduate research problem.

A preliminary investigation of the production of low-volatile char by the fluosolids technique has shown that this process is limited to successful treatment of coals in the finer sizes. It does not seem feasible to attain a satisfactorily uniform product in the larger sizes required by the phosphorus industry with the fluosolids technique. Consequently, other processes such as are now in use both in the lignite industry and at the plant of the Kemmerer Coal Company seem to offer the best promise for industrial success. The problems of recovering, purifying and separating the volatile constituents produced in the charring of Wyoming coals have been given considerable attention in recent months and it is believed that a better knowledge of the effect of retorting conditions on the gases produced and more information as to the constituents in the tars and their characteristics may have considerable value in the economics of their utilization. Accordingly, precision small scale retorting equipment with full recovery and separation methods has been installed in the coal laboratory. It is expected that results obtained in testing and analyzing the products of retorting of coals will be of real value in assessing the commercial treatment of the coals.

Equipment for ultimate analysis of coals has been acquired, and this makes possible a further service in connection with assaying coals as well as research on coals. The ultimate analysis equipment will also be valuable for investigation of chars and condensible volatiles.

Major emphasis on petrolum research continues to be focused on removal of sulfur, from high sulfur crudes. Several methods of producing low sulfur light fractions from high sulfur crudes are in use by the

industry, but most of these processes concentrate the sulfur in the asphaltic residuum. This limits the use of the asphaltic materials. For example, the asphalts thus enriched in sulfur are worthless for manufacture of a low sulfur petroleum coke such as is required for production of metallurigcal reducing agents or electrodes for the aluminum industry. Removal of sulfur before or during distillation which would enable producation of a low sulfur asphalt would open up new possibilities for wider usage of the asphalts from high sulfur crude petroleums, as well as the possibility of better yields of low sulfur lighter fractions.

Bentonite, iron ore beneficiation, work in connection with the processing of anorthosite for alumina production, and use of residues from the process for Portland cement manufacture have been the subjects of short term investigations.

The briquetting plant has been operated on a custom basis for the Kingsford Chemical Company of Iron Mountain, Michigan and also for the Pierce Management Company, Scranton, Pennsylvania.

Investigation of production of a fortified plant nutrient vermiculite product for the Mikolite Mining and Development Company, Encampment was carried on during the year.

In addition to the major phosphate research on defluorination of phosphate rock which has been in progress in cooperation with Phosphate Minerals, Inc., of Kemmerer, engineering and plant operation consultation services have been rendered to the same company.

The Sulphite Pulp Manufacturers' Research League Project was renewed for a third year and after a steering committee meeting at N.R.R.I. November 24, 1952, work on the project for the current year

was reoriented. Following the decisions reached at this conference, current work on the chemical phase of the project was terminated and further efforts have since been concentrated on the investigation of sulphite liquor for use in highway construction. Studies have also been undertaken on the effect of aggregate type and grading, curing treatment and other factors upon sulphite bound aggregate paving. The Marshall test has been adapted as a measure of certain physical characteristics of various mixes. Laboratory tests here have paralleled test road work in Wisconsin and an accelerated simulated service test called the "wheel" test has been developed and put into use in the project.

The U. S. Army Ordnance Corps project, "Lime Bonded and Stabilized With Titanium Oxide as a Refractory for Special Applications", was renewed for a second year effective March 12, 1953. This project involves fundamental research on lime bonded and stabilized with titania. Results of the research which is carried on under the sponsorship of the Office of Ordnance Research will be used as Ph. D. thesis material by Mr. Robert L. Eichelberger.

COAL RESEARCH

Following up the carbonization tests carried on during the fiscal year 1951-52 for the Victor Chemical Company, a series of fluo-solid tests was run to evaluate the prospects of utilizing this process for the charring of western coals. These tests were discontinued when it was found that more conventional processes (recycling gas or indirectly heated carborundum retorts) are preferable for the production of a low volatile char with good physical strength. Cost estimates were prepared on a charring plant in the Lake De Smet district to serve the Montana market for reducing char.

During November N.R.R.I. entered into cooperative work with the Pierce Management Company, of Scranton, Pennsylvania, on an investigation of the briquetting qualities of a sub-bituminous coal from Burma, as well as char produced from this coal. As this coal weathers rapidly, it is unsuitable in its raw state for industrial firing, and must be converted into a product with greater stability. Briquets produced here were pronounced satisfactory by the user. The work was prolonged, as parallel investigations did not show the same favorable results shown here and necessitated check runs. This work was sponsored by Mr. C. E. Lesher, Pittsburgh.

During the month of December, briquetting tests sponsored by the Kingsford Chemical Company of Iron Mountain, Michigan were run on charcoal with spent sulphite liquor binder. De-airing was finally recommended to the sponsor and it was considered that such procedure would be necessary for the production of firm enough briquets.

Equipment suitable for de-airing the mixture was located at the Bonnot Company, Canton, Ohio. During April, the plant of the Kingsford Chemical Company at Iron Mountain, Michigan was inspected and plans were submitted for the conversion of one of their briquet dryers to a devolatizing furnace. Suggestions were also submitted regarding the rebuilding of the remaining dryers to increase their capacity.

In February tar from the new charring operation of the Kemmerer Coal Company was investigated and its use as wood preservative recommended. Further work on the tar was carried on in order to find the most suitable use for the tar residue or pitch.

During September about a dozen coal mines were sampled in the northern part of the state. Proximate analyses were made on each sample collected and reports were sent to the mines. Various other test work included a number of heating value determinations, carbonization tests for several Wyoming interests, and fuel tests for mines in the State.

Early in the fiscal year the work on fluo-solid carbonization was discontinued. Results of a series of runs indicated that this process should be confined to the treatment of fines of not over 1/4" in size. The potential demand for char from Wyoming coal, however, seems to be primarily for larger sizes. For the production of larger size char there are available the Lurgi low temperature carbonization process which is in operation in many countries and the Petrocarb process as used at the Kemmerer Coal Company plant which yields a good char, and seems only to require process refinements. It appeared logical to start a series of fractional carbonization tests to determine the gas constituents formed at various temperatures.

[illegible]

[illegible] making [illegible] of the [illegible]

[illegible] company [illegible]

[illegible] for the company [illegible]

[illegible] furnace. [illegible] were also submitted regarding [illegible] of the [illegible] to increase their capacity.

In addition, but from the [illegible] deposit [illegible] of the Kemmerer Coal City on an investigation and it [illegible] most conservative recommendation. [illegible] on the [illegible] in order to find the [illegible]

[illegible] more [illegible] mines [illegible] samples in the [illegible] of the [illegible]. Structure analyses were made of each [illegible] and report [illegible] to the mines. [illegible] other [illegible] including a number of [illegible] determinations, [illegible] the general [illegible]

[illegible] the fiscal year [illegible]

[illegible] results [illegible] conditions [illegible]

[illegible] countries and the Petro- [illegible]

Results of these tests will be useful in the design of a retort of the indirect fired type and will be helpful in producing by-product gas of desirable character.

A barrel of creosote oil was obtained from a North Dakota Lignite charring plant for the purpose of investigating its possible utilization as a source of coal tar chemicals. This oil is a product distilled from coal between 200 and 350°C. The crude oil has been separated into fractions of acids, phenols, amines and a neutral oil consisting of a few oxides and ketones but mainly of hydrocarbons of which a considerable portion seem to be of an aliphatic nature. About 30 liters of the crude distillate have been treated in this manner. The phenols, amines and neutral oil classes have been fractionated into small groups of compounds by means of a fractionating column. Refractionation of the starting fractions has been done to gain further separation into groups containing only three to five compounds per fraction. This process has been used in preparation for further separation and identification of individual compounds when sufficient material has been processed and time permits. It is estimated that the neutral oil fraction contains some 250 compoundsboiling between 32.5 and 335°C. at atmospheric pressure at this elevation. Qualitative tests indicate considerable unsaturation in the hydrocarbon fractions. Further studies are planned for determination of the character of these unsaturated compounds and their possible use as monomers in the manufacture of high polymers.

Several of the acids have been tentatively identified and indicate alphatic, cyclic and benzenoil structures. Considering the derivation of these acids, it seems that a mixture of alphatic, cyclic and benzenoid series of compounds would be present in all classes of compounds in this creosote oil of lignite origin.

A study of coal tar distillate derived from Wyoming sub-bituminous coal is planned to run parallel with the investigation of lignite creosote oil.

The market shortage of many coal tar chemicals and the expanding utilization of these compounds in a rapidly growing chemical industry warrants the investigation of the tar distillates of these coals which are in considerable supply in Wyoming.

During the year, the chief emphasis has been on the determination of colloid particle size in the coal extracts from chlorination.

Preliminary dialysis to yield a colloid not passing the membrane served to eliminate the low molecular weight material.

Several osmometers were constructed after the general lines described in the literature. The latest design has two improvements which experience showed were desirable. A stopcock on the filling arm and a complete immersion of the cell and capillaries in the solute gave better performance.

The osmotic measurement of the molecular weight showed the degree of the degradation of the colloid size; before chlorination - m.w. 32,900, after chlorination - m.w. 7,500-8,000. Further work on extracts of raw coals has shown a regular relation of the colloid particle size with coal rank and coking property. A low-rank non-coking coal has a high colloid particle size.

The dialyses mentioned above give promise of being a valuable step in future isolation work. The crystallization of compounds from the solutions seems to be facilitated by removal of the colloid material.

The analysis of the chlorinated coals for chlorine and fluorine has been carried out in a combustion apparatus. The results indicate we have a dependable method for these materials that can be used in more exact studies of the reaction products.

PHOSPHATE RESEARCH

The work directed towards beneficiation of the high-lime Wind River phosphate rock, which has occupied the attention of the group for the past several years, has been abandoned, at least temporarily, because the lime present becomes chemically fixed during the calcining treatment and cannot be removed by practicable means. This was checked by adding more lime and finding it impossible to recover even this added lime or to get it to report chemically as "free lime".

The efforts started last year towards producing a low fluorine phosphate product which can enter the market as a mineral supplement have been actively pursued. Most of the work on this project has been concerned with building a laboratory rotary kiln in which the phosphate rock could be melted. This has been slow and there have been many changes and modifications in kiln design and method of keying in the refractory during the course of the year. There has evolved, however, a furnace that gives considerable promise of standing up quite well under an extended period of melting when this can be undertaken.

The original titania-bonded lime lining is still in the central part of the furnace and to all appearances is as good as ever after several days of operation at temperatures in the range under which melting is accomplished. Months of shut-down have intervened between runs.

Phosphate rocks from three different localities have been melted in tests extending over eight hours each. Each of the rocks sinter at temperatures just above 2000°F. and begin to melt at about 2550°F. After the first appearance of melting, the mass becomes very viscous, possibly due to a readjustment in mineralogical composition, and the mass tends to consolidate itself into a sintered ring around the inside of the rotary back of the melting section which gradually grows and, if allowed to continue, would seal the opening completely. It has been necessary to dislodge parts of this ring by poking it with a long bar so as to advance the material into the true melting zone where the temperature is between 2750 and 2800°F. Once the pasty mass enters this zone, melting has been complete and rapid and only a thin film of non-viscous melt is present on the bottom of the shell at any time. The melting zone has been short; about two feet long in the case of the Wind River Mountain rocks and only one foot in the case of the Sage rock. Defluorination has not been complete in that between 0.2% and 0.4% F. was contained in the melted product. It is hard and apparently a true glass. It is believed that during the longer retention time that would result in a commercial kiln, a greater fluorine elimination would result.

Two problems require further study before this process is considered commercial. The first has to do with the stability of the lining under extended periods of service. Free lime is not in equilibrium with the melt under conditions of operation but there are two high melting-point compounds possible (with some mutual solid solution probable) between materials such as the molten Wyoming rock and a melt in equilibrium with free lime. Either of these materials

should serve as a solid interfacial coating of the original lime lining and be resistant to appreciable chemical attack by the molten mass. On those tests where rodding of the viscous ring has had to be resorted to, there has been a visible attack on the lining and the product is much higher in CaO than the original feed. However, one test, was conducted in such a manner that the material rodded into the melting zone did not come from close to the lining and there was little or no pickup of lime during the short melting period.

The other problem has to do with the formation of the upper ring at the head of the melting zone. This has been attacked in commercial kilns in a number of different ways but whether any of these or a different one would be applicable is not known at this time.

The addition of lime to certain Wyoming phosphate rocks to delay or prevent melting,thereby permit heat treatment in the defluorination range,continues to be interesting. This would permit treatment of the rocks in kilns lined with ordinary high temperature refractories but yields a product lower in phosphorus content than the original rock. Additional work is in progress on this operation at the present time in an effort to produce a product carrying about 10-11% phosphorus and fluorine sufficiently low to permit its use as stock food.

During the year, some attention has been given to the economics of the different ways in which phosphorus enters the market and thereby show what is required for an economic operation based on Wyoming phosphate rock. This work is being continued.

PETROLEUM RESEARCH

Work has been continued on the desulfurization of high sulfur crude petroleum, a different approach having been taken on this problem during the current year following a survey of the literature on removal of sulfur by catalytic hydrogenation.

The literature shows that many attempts have been made to find an economically feasible means of desulfurization by this method. Success has been attained by research in this field with the distillation products from crude oils in which catalytic hydrogenation takes place in the vapor phase. A number of catalysts are listed which successfully remove sulfur from many sulfur compounds as hydrogen sulfide and several patents have been issued covering catalysts and specific methods for this procedure.

In the treatment of crude oil by direct catalytic hydrogenation, little success has been found. The asphaltic materials soon coat the surface of the catalytic agents rendering them inactive in the hydrogenating process. Because the process must be carried out in the liquid phase, contact of the resinous materials with the surface of the catalyst causes it to become useless in a short period of time. The average unit volume ratio of crude oil to catalyst was found to be about 1.5 to 1 which is much too low as an industrial procedure.

Attention has been turned to hydrohalogenation as a more feasible means of desulfurization of high sulfur crude oils. Hydrofluorination of crude oil for the purpose of removing the greater quantity of sulfur and sulfur compounds was proposed as early as 1936 but only a few

laboratory trials have been recorded since that time. Because of the beneficiation of distilled products reported from the hydrofluorination method of desulfurization, it was decided to experiment with dry hydrogen fluoride and with dry hydrogen chloride as desulfurization agents for high sulfur Wyoming crude oils.

Preliminary tests with hydrogen chloride have shown that about 70 percent of the sulfur may be removed in a single treatment from a crude oil containing 3.86 percent sulfur. This crude oil contains about twice the amount of sulfur contained in the crude oil treated with hydrogen fluoride as reported in the literature. The gasoline and kerosene distilled from the hydrogen chloride treated crude oil showed about 40 and 50 percent respectively less sulfur than these products distilled from the untreated crude. The sulfur remaining in these fractions was in the form of mercaptans, whose sulfhydryl groups are not attacked by hydrogen halides. However, the mercaptains are readily removed by other processes either in the vapor phase during distillation or in the liquid phase following distillation. The diesel fuel and gas oil fractions showed a decrease of nearly 80 percent in sulfur content and the residue remaining showed a sulfur loss of about 65 percent. This appears possibly to be a workable method for desulfurization of crude oils but further investigation and refinement of procedures are necessary before any final conclusions may be drawn.

Equipment has been set up for hydrofluorination of crude oils and experiments are underway for a study of this method.

In one test run, a small quantity of asphalt dissolved in a light hydrocarbon solvent was treated with dry hydrogen chloride. The recovered asphalt after treatment with hydrogen sulfide had a sulfur content

of 1.36 percent compared with 4.87 percent sulfur content of the original asphalt. This experiment showed that about 64 percent of sulfur may be removed from asphalt with one application of hydrogen chloride. Further studies of this problem are planned for the next year.

SULPHITE PROJECT

The object of the Sulphite Project which is sponsored by the Sulphite Pulp Manufacturers' Research League, Inc., Appleton, Wisconsin, is to determine if admixtures of spent sulphite liquor (waste product of the paper mills) stabilize asphalt and if so, by what mechanism. The immediate objective following deferment of work on the principle objective through steering committee action has been to study application of spent sulphite liquor to the reconditioning of asphalt roadways. This has been extended to studies of the bonding of graded fresh aggregate with spent sulphite liquor.

A series of reactions were run on various percentage mixtures of asphalt and 50 percent spent sulphite liquor containing 50 percent calcium lignosulfonate solids. The percentages of lignosulfonate in the reaction mixtures varied from 5 to 33 percent on the solids basis. The mixtures were reacted for a period of 5 minutes at 300°C., then spread into a thin sheet and put aside to dry. Three grades of asphalt were used in these experiments. The reaction products varied from hard, brittle substances, to flexible, rubber-like products. Analyses of these reaction products showed that a small amount of the asphaltenes were lost to the benzene insoluble lignosulfonate material. The amount of asphaltenes so bound to the lignosulfonate was in direct proportion to the lignosulfonate solids in the reaction mixture. This phenomenon

was interpreted as an indication that a reaction had occurred between this fraction of the asphalt and the lignosulfonate material present in the reaction mixture. No further experiments were carried out in an attempt to investigate the effect of varying time, temperature and water content in these reaction mixtures. Both lignosulfonate and asphalts have a considerable degree of reactivity and it is thought that the condensation between the two substances could be greatly increased.

Analyses of catalytic and straight run asphalts were made for comparison with the asphaltic-lignosulfonate products mentioned above. Several analyses of asphaltic material from old road beds were made to determine what occurred to the asphalt in the aging process. It was found that during aging, the acid materials increased greatly, the asphaltenes doubled in quantity, with a correspondingly decrease in oily constituents and the asphaltic resins remained about constant.

In the aggregate bonding investigation, various tests have been adapted to the evaluation of aggregate sulphite liquor mixes. These include compression, flexure, the Marshall test, and sonic non-destructive testing. The results indicate that sulphite bound aggregate forms a semi-rigid somewhat elastic type of unit, perhaps intermediate between relatively non-elastic concrete, and the more yielding asphaltic bound type of body. In order to obtain actual service results on sulphite bound paving section at an accelerated rate, a simulated service test known as the "wheel test" was developed and placed in operation. In this test, a heavily loaded rubber tired wheel is caused to roll continuously over a series of prefabricated test

sections arranged circumferantly end to end. Each test section is subjected to exactly the same wear as the other sections and a rapid comparison of the wear resistance or relative breakdown of the various sections is thus obtained. The wheel test is proving of great value in investigating the various factors in construction of test road sections bound with sulphite liquor.

ORDNANCE PROJECT

The U. S. Army Ordnance Corps sponsored project was renewed, as of March 12, 1953 for a second year. This project is an outgrowth of research started several years ago by the Institute. This was a search for a refractory which could stand up in contact with molten phosphate rock. Such a material was found in calcium oxide bonded with titania (titanium dioxide). Through the work sponsored by the Office of Ordnance Research, the fundamental aspects of the project are under study. As mentioned under phosphate research, the application and use of the refractory are under development for defluorinating phosphate rock.

MISCELLANEOUS

During the year, a magnetic concentration study was made on some iron ore from Fremont County and it was found possible to concentrate and recover most of the contained iron oxides in a product carrying more than 60 percent iron.

Two short term projects in connection with the process for making alumina from Wyoming anorthosite were conducted.

Some studies were conducted on a product made by adding plant food elements to expanded vermiculite for the Mikolite Mining and

Development Company, Encampment.

The Institute has continued its work in bentonites and has conducted tests for private concerns to measure the performance of bentonite samples submitted.

FUTURE PLANS

During the forthcoming year, it is planned to continue major invesitgations in the principal resource fields namely fuels and nonmetallics. Work as in the past will be pointed toward more fundamental information regarding these resources so that their greater utilization may result. Upgrading or beneficiation of raw materials remains one of the major problems in many cases. The program of the Institute will continue to be carried out in conjunction with and in cooperation with other agencies and organizations working on regional resources, whether they be state, federal or private. The facilities of the Institute continue to be available for programmed research where such projects can be fitted into the existing facilities and work in progress.

An important part of the Institutes service to the University and the College of Engineering is in giving practical experience in science, engineering and laboratory work to graduate and undergraduate students. In so far as budget permits, part-time work will be given to worthy and capable students, as project assistants.

Great need exists for a better knowledge of coal and petroleum, particularly to enable their wider utilization. These two substances which in the past have been looked upon mainly as fuels should be more generally recognized as chemical source materials. New knowledge will aid in deriving from each, basic substances, for higher unit cost chemicals and intermediates.

There is under consideration a program for the development of industrial carbon. It appears that suitable activated carbon can be produced from northern Wyoming sub-bituminous coals. There is also considerable demand for electrode carbon in the Northwest, and the possibility of filling this demand from Wyoming coals looks attractive. At this time, however, it appears that the development of activated carbon is more promising in so far as favorable results can be expected sooner and with lower cost.

It is regretable that more is not known as to the actual extent of certain mineral and metal resources in the state, examples are tungsten ore, fluorspar, allanite, kyanite, vermiculite and uranium ores. Problems of extracting the values from such ores confront us but we hesitate to expend valuable research effort on a resource, the tonnage of which could later be found to be insufficient to warrant working out a process for its treatment.

With the exception of bentonite and two or three common brick clays, practically nothing is known of the ceramic raw material resources of Wyoming. About $10,000 a year would be necessary to start a full time study of the ceramic resources of the state. Such a project would require field work, hand in hand with laboratory investigations, and could perhaps lead to a ceramic industry in Wyoming, such as is found in both Colorado and Utah.

Electro-reduction of aluminum direct from ores is another problem which should be given attention. A newly reported process might be applicable to anorthosite, as well as low grade bentonites and other clay like materials, occurring abundantly in Wyoming.

Analcime - a naturally occurring zeolite has been reported, in at least two periodicals, to occur in quantity in the Triassic Chugwater formation within the state. Research might develop uses and markets for this potential resource.

These examples of undeveloped or only partially developed resources illustrate the practically unlimited possibilities for developments of the resources of the state.

As budget availability permits, it is planned to undertake investigations in the more promising fields indicated.

SPECIAL STAFF ACTIVITIES

1952

June 30-July 3	Walter E. Duncan traveled to Sundance, Wyoming per request of the J. R. Simplot Company and the Chicago and North Western Railway System.
September 7-13	Edward Prostel went to Sheridan to sample coal in connection with coal sampling program.
September 22	H. G. Fisk went to Cheyenne to attend a conference of power companies and Victor Chemical Works.
September 22-28	Neal Rice traveled to Rhinelander, Wisconsin to attend meetings on sulphite research.
September 24-27	H. G. Fisk was in Denver at the American Mining Congress meetings.
September 25-26	Edward Prostel was in Denver at the American Mining Congress meetings.
October 6-10	H. G. Fisk made a trip through central and western Wyoming, returning via Kemmerer and Green River, to gain first hand information on current operations and industrial activities.
October 14	Neal Rice went to Denver to confer with Colorado State Highway Department and officials relative to the acquisition of equipment for the sulphite project.
October 16-19	A conference on Atomic Energy Education was attended at Alburquerque, New Mexico by H. G. Fisk, who represented the College of Engineering.
October 20	H. G. Fisk went to Cheyenne and Casper at the request of the Wyoming Natural Resource Board to attend power conferences.
October 29-31	A Wyoming Section A.I.M.E. meeting was attended and participated in by Neal Rice, Edward Prostel, Walter E. Duncan and H. G. Fisk.
November 9-10	H. G. Fisk made a trip to Lander to meet with Mr. George A. McHugh and Mr. J. R. Simplot and visit iron ore deposits near Lander.

December 8-12	H. G. Fisk and Walter E. Duncan traveled to Lake Superior Iron Ore District to visit iron Ore beneficiation operations and laboratories.
December 17-19	Walter E. Duncan went to Kemmerer, Wyoming to assist the personnel of Phosphate Mines, Inc. in starting up their Rhenanian fertilizer operation.
1953	
January 12-14	Neal Rice and Edward Prostel traveled to Kemmerer, Wyoming to discuss coal production and carbonization with officials of the Kemmerer Coal Company and others.
February 13-14	Mr. Rice traveled to Denver, Colorado to pick up map at Bradford-Robinson Printing Company and attend sessions of the Colorado Mining Association.
February 3	Ralph D. Law gave a talk to the American Society of Mechanical Engineers concerning the work in progress at N.R.R.I.
February 17	Dr. Law gave a talk on applied chemistry as used at N.R.R.I. before a meeting of the American Chemical Society to which approximately 100 college and high school students were invited.
March 6	H. G. Fisk attended a luncheon in Denver as the guest of the Magma Corporation.
March 10-11	Edward Prostel traveled to Denver.
March 16	H. G. Fisk presented a paper, "Wyoming Resources for the Chemical and Metallurgical Industries", before the Division of Chemical Marketing and Economics, American Chemical Society, Los Angeles.
March 25	The meeting of the Missouri Basin Inter-Agency Committee at Torrington was attended by H. G. Fisk in the company of Dean H. T. Person.
April 2-3	Mr. George A. McHugh of the J. R. Simplot Company was accompanied to Casper and Thermopolis by H. G. Fisk. During his visit at Laramie, a conference was held in connection with the Lander iron schist deposits upon which Mr. Duncan carried on additional beneficiation studies.
April 16	H. G. Fisk presented a summary statement on the functions and activities of N.R.R.I. before the Wyoming Natural Resource Board at Casper.

April 18-22	Edward Prostel acted as N.R.R.I. consultant to the Kingsford Chemical Company at Iron Mountain, Michigan.
April 30-May 3	The Colorado Academy of Science Meetings at Colorado Springs, Colorado were attended by Raymond F. Stevens.
June 9-12	H. G. Fisk and Edward Prostel traveled to western part of Wyoming to sample coal mines.
June 21-22	In order to confer with officials of Phosphate Minerals, Inc., and of the U. S. Department of Agriculture on Phosphate Research, H. G. Fisk and Walter E. Duncan went to Kemmerer, Wyoming.
June 28-July 2	Mr. Edward Prostel traveled to Glenwood Springs, Colorado to attend meeting of Rocky Mountain Coal Mining Institute and also went to Rifle, Colorado to visit at Oil Shale Demonstration Plant of the U. S. Bureau of Mines.

COMMITTEE ASSIGNMENTS

During the year, H. G. Fisk retired as chairman of the Wyoming Section of the American Institute of Mining and Metallurgical Engineers and became a member of the Executive Committee. He also served as a member of the Board of Trustees of the Colorado-Wyoming Academy of Science, Research Foundation and as Vice-chairman, Phosphate Task Force, Columbia Basin Inter-Agency Committee. University committees on which he served were Secretary of the Executive Committee of N.R.R.I., the Graduate Research Council, the University Patent Committee, and the Central Committee of the College of Engineering.

Mr. Walter E. Duncan served as Western Vice Chairman of the Milling Methods Committee of the Industrial Minerals Division of the American Institute of Mining and Metallurgical Engineers and as a member of the Engineering College Committee on Evaluation of Engineering Education. He also served as Secretary of the Wyoming Section of the American Chemical Society.

Mr. Raymond Stevens presented a paper on Coking Theory at the Colorado-Wyoming Academy of Science Meeting on May 1. Mr. Stevens was a member of the membership committee for the American Chemical Society.

Mr. Neal Rice, as Program Chairman for the 3rd Biennial Briquetting Conference to be held in Banff, Alberta, Canada, August 31 and September 1, made arrangements for the Conference and its program.

A paper entitled "Problems in Processing Wyoming Phosphate Deposits" was presented at the Annual Meeting of the Wyoming Section of the American Institute of Mining and Metallurgical Engineers held in Casper October 31, 1952 by Mr. Duncan.

magnetic methods. Mr. King's report and maps have been reproduced and made available for general use.

MISCELLANEOUS ACTIVITIES

Portland Cement

A satisfactory Portland cement has been produced from raw materials obtained in the vicinity of Orin Junction through the cement raw materials survey conducted by Mr. Ralph H. King, during September 1949, through the support of the Chicago and Northwestern Railway System.

Materials suited to cement manufacture as found in this survey are a limestone exposed 5 3/4 miles south of Manville and a shale exposed 6 1/2 miles west of Orin Junction.

Titanium Alloy

Several attempts have been made to prepare a low carbon alloy of titanium and iron. It is known from previous trials that such an alloy will have exceptional physical properties. Temperature conditions involved are severe, and crucibles must be of a special type to withstand the conditions imposed in melting. A new gas fired furnace is being constructed for this project.

Concrete Aggregate Research

Dr. Harold S. Sweet of the Civil Engineering Department has carried on research on the evaluation of Wyoming concrete aggregates in cooperation with N.R.R.I. The Institute has supported this work with financial and other aid.

Assay and Analytical Service

The chemical laboratory has processed a large number of samples, both in connection with N.R.R.I. investigations and other work.

N.R.R.I. projects involving a large number of analyses made include the phosphate work, coal research, the iron ore survey, the cement materials survey, [illegible] have been completed for the [illegible]

[illegible]

[illegible] survey [illegible] during September 1935, through the support of the Chicago [illegible]

[illegible] materials to cement manufacture as found in this survey are a limestone deposit 5 3/4 miles south of [illegible]ville and a shale deposit 6 1/2 miles [illegible] of [illegible] Junction.

[illegible]

Several attempts have been made to prepare a low carbon alloy of titanium and iron. It is clear from available data that such an alloy will have exceptional [illegible]

[illegible]

Mr. Arnold G. [illegible] of the [illegible] Engineering Department has carried on research on the [illegible] of [illegible] concrete [illegible] in cooperation with [illegible] The [illegible] was supported [illegible]

[illegible]

The [illegible] in connection with W.P.A. investigations and other work.

W.P.A. projects involving a large amount of [illegible] include the [illegible], coal resources, the [illegible] survey, the cement materials survey, and some clay research.

FUTURE PLANS

Many of Wyoming's mineral resources are marginal under present economic conditions, present mining and transportational costs and presently known treating or processing methods. Two broad lines of attack on wider utilization of these resources are open. First, up-grading, purifying and concentrating the raw materials so as to decrease the cost of moving them to the points of conversion or consumption; and secondly, processing them locally into more concentrated or valuable commodities such that the cost of transporting them to markets will be o less consequence.

Drying and briquetting high moisture coals is an example of the first meth of reaching wider markets. Producing concentrated superphosphate or elemental phosphorous from phosphate rock illustrates the second method.

Institute projects should continue to be channeled along both of these lines with emphasis on production of the finished or semi-finished product within the borders of the state. As the higher grade or more accessible raw resources in other parts of the country become depleted or subjected to higher production cost resources occurring in Wyoming will be placed in a relatively more favorable position.

For the immediate future it is planned to carry to logical conclusion the specific research projects now in progress on the benefication and processing of the intermediate grade phosphate deposits of Central Wyoming. Whether or not the economics of processing these deposits work out successfully at the present time, and under conditions of existing competition, this information will be vital to the eventual exploitation of these deposits, which is bound to come.

work, emphasis should be placed more and more upon subbituminous coa

uid fuels and chemical intermediates. As demands for

W98
1954/55

ELEVENTH ANNUAL REPORT

June, 1955

NATURAL
RESOURCES
RESEARCH
INSTITUTE

THE LIBRARY OF THE
JAN 9 1963
UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING

The University of Wyoming

Laramie, Wyoming

ELEVENTH ANNUAL REPORT

June, 1955

NATURAL RESOURCES RESEARCH INSTITUTE

COLLEGE OF ENGINEERING

The University of Wyoming

Laramie, Wyoming

333.7
[illegible]
[illegible]

TABLE OF CONTENTS

Page
TEN YEAR SUMMARY 1

NONMETALLIC MINERALS RESEARCH. 6

    PHOSPHATE INVESTIGATIONS 6

    MISCELLANEOUS ACTIVITIES 8

    CIVIL ENGINEERING TESTING LABORATORY RESEARCH 9

COAL RESEARCH. 12

PETROLEUM RESEARCH 15

TEN YEAR SUMMARY

In 1945 the first annual report of the Natural Resources Research Institute covering activities during its first year was issued. By the time the Institute had been operating a year the problems confronting resource development in Wyoming were pretty well understood and the main program of N.R.R.I. was under way. During the ensuing ten years activities were channeled into most of the major resource areas of the state, and the staff and physical plant of N.R.R.I. were greatly increased and strengthened.

Over the ten-year period the Institute has served the University and the state in many ways, however the main purpose of the Institute as set forth in the University regulations is as follows:

> The purpose of the Natural Resources Research Institute shall be to initiate and conduct scientific, technological, and economic studies of the resources of Wyoming with a view to the industrial utilization of Wyoming's natural resources and the future industrial development of the state.

In activating this program the Institute has carried forward both short- and long-term research and has become a center for information on Wyoming's resources both as regards their technological and economic factors.

The Institute has made available results of its studies through publications, correspondence with individuals and corporations, and personal contacts. It has served as a training center where a select

group of students gain practical experience in chemical engineering and mineral technology. The Institute has sponsored conferences in technical fields and staff members have presented papers before scientific groups and societies. Staff members have been active in national and local scientific and engineering organizations.

Principal fields of activity in which the Institute has made contributions to resource development are nonmetallic mineral resources and fuels. Bentonite testing and phosphate processing were among the first problems given an active place and much of the work in these fields has been carried on under contracts. Coal has been the subject of a substantial amount of Institute sponsored work and considerable work in this field has also been carried on under outside sponsorship. During the last four years research on the black oils of Wyoming has been undertaken and results of this research are just becoming apparent. Forty companies have sponsored or underwritten work of one type or another at N.R.R.I. during the ten-year period of its activity.

Ten years ago the staff of the Institute consisted of the director, a part-time secretary, a chemist, and an assistant. The present full-time staff of the Institute consists of the following persons:

Henry G. Fisk	Director
Walter E. Duncan	Chemical Engineer
Neal Rice	Coal Research Chemist
Edward Prostel	Coal Research Engineer
Ralph D. Law	Petroleum Research Chemist
Raymond A. Morgan	Head, General Engineering (Part Time)
Donald R. Lamb	Assistant Professor, Civil Engineering (Part Time)
Raymond F. Stevens	Analytical Chemist
Oren Neal	Mechanic
Ruth McEllhiney	Secretary

In addition to the full-time personnel there have been from four to six part-time student assistants employed at N.R.R.I. during each academic year.

In 1947 the Institute moved from an office in Science Hall, with laboratories in the engineering building, to the former Bureau of Mines petroleum laboratory building and started a rather rapid growth in physical plant. To house the coal drying and briquetting project sponsored by the Department of Commerce a brick building was constructed for the coal work.

In 1950 the offices of the Institute were moved to the newly completed office structure on Lewis Street and laboratory space became available for a petroleum laboratory. At the present time the floor space of N.R.R.I. comprises approximately 8,000 square feet.

During each year since its establishment, the basic equipment of the Institute has been added to. Acquisition of equipment has been largely financed through sponsored research and has enabled building up of facilities which are reasonably satisfactory for the work in progress.

The following laboratories are equipped with modern facilities:

sample preparation room
analytical and assay laboratory
mineral processing laboratory
organic laboratory
coal laboratory
petroleum laboratory
ceramic and clay laboratory

In addition to the laboratories listed pilot plant equipment for semi-plant scale projects has been installed in the phosphate and coal plants.

Several Institute projects have involved research of a fundamental or long-range type.

In the coal field fundamental questions regarding the constitution of coal have challenged investigators for many years and some work in this area has been undertaken as time and budget have permitted.

In connection with the coal carbonization work, now being more actively attacked, it has been recognized that the liquid products of low temperature carbonization - the tars and tar oils - must be better understood if they are to be utilized effectively by industry. This problem has been apparent for many years, and has been worked on by numerous investigators. Work now in progress on processing the tars and liquid fractions of coal carbonization is both fundamental and practical.

Studies on the defluorination of phosphate rock have revealed certain discrepancies in the published equilibrium diagrams involving the calcium-silica-phosphate system. It is believed that a better understanding of the mutual relations of the phases in this complex silicate system may lead to more satisfactory defluorination of phosphate rock by thermal means and to improved availability of calcium phosphates for agricultural uses.

Research in petroleum has, during the last two years, shown the importance of fundamental studies in characterizing the hydrocarbons in petroleum and in the products of hydrogenation of the less desirable black oils.

Among its functions and activities the public relations activities of N.R.R.I. are of considerable importance. For example, the assay and

analytical service of the Institute goes far beyond its main purpose as a service department. Through contacts with individuals and groups much information and advice is given the public regarding resources and mineral development possibilities. In many instances the principal contact many people have with the University is through N.R.R.I. laboratories or through some phase of the Institute program.

The Institute has cooperated with other units of the University and with various state and Federal agencies and its activities have supplemented and been coordinated with those of these departments.

Perhaps the principal means of making available to the public results of the research work and the information developed in the N.R.R.I. program is through the publications of the Institute. The first Institute publication, Bulletin No. 1, "Certain Chemical and Physical Properties of Several Wyoming Coals," was issued in 1946. Since that time thirty-four publications in various categories, not including the annual reports of the Institute, have appeared.

As a supplement to this report a list of companies sponsoring research or tests at N.R.R.I. during the past ten years is appended.

NONMETALLIC MINERAL RESEARCH

Phosphate Investigations

The major activity in inorganic mineral research since 1945 has been a study of phosphate rock processing which has been particularly applied to the phosphate rock of the Wind River Mountains in Fremont County. Cooperative studies with the Wyoming Geological Survey and U. S. Geological Survey published as Wyoming Geological Survey Bulletin 37, indicated a considerable area and tonnage of medium to low grade rock amenable to relatively simple mining. Later the U. S. Bureau of Mines extended this prospecting in a southerly direction and furnished the N.R.R.I. with a 50-ton sample of rock from a shaft on what has come to be known as the Twin Creeks Tract. Two major sponsors have privately underwritten a very large share of the laboratory work done on the Fremont County deposits.

The work has been channelled along three major lines: (1) High temperature processing to produce a partially defluorinated rock of high phosphorous availability for fertilizer use or highly defluorinated rock to be used as animal feed supplements; (2) Beneficiation to separate the phosphate mineral from impurities present; and (3) Economic studies of a large variety of processes to indicate probable degree of success or failure if such processing were applied to Wind River mountain rock.

Technical success can be reported in production of phosphatic fertilizer grade material by heat treating the raw rock. The fertilizer, however, is not of a type that meets western requirements and hence is not to be recommended for wide use in this area. Production of very low fluorine products also has been technically proven using the sintering process but additional work will be required to develop operating details

on the process employing rotary kiln melting of the rock. There is a small profit margin indicated to an operation producing the sintered phosphate feed supplement but the marketing area is small and activity in allied fields indicates a probable shrinking of even this limited area.

The beneficiation studies have not been fruitful in that the impurities are very intimately associated with the phosphate mineral and even fine grinding effects only partial liberation. A semi-chemical approach was studied quite extensively as a result of some indication of success from small tests. This success was not borne out by larger scale studies.

The economic studies have pointed out that utilization of the Fremont County phosphate rock is dependent upon the availability of very low-cost hydroelectric, or steam, power or low cost sulfuric (or possibly nitric) acid.

Other phosphate work has involved production of a lime-soda phosphate known as Rhenanian phosphate for a private sponsor. All of the phosphate studies are to be reported in an Institute publication to appear soon as N.R.R.I. Bulletin No. 6.

In the course of the phosphate investigation, a refractory ceramic composition was developed which had favorable properties for use in the presence of phosphate melts. A patent, assigned to the University, has been allowed on this refractory and a two-year study, sponsored by the Ordnance Department of the U. S. Army, developed further information about the properties of the refractory.

In the course of the work to date two series of high temperature reactions appear to warrant further detailed study. The first is a reaction at 1500 to 1800° F, which interfers with the separation of the

excess calcite in the rock and the second involves a study of the changes in crystal makeup during high temperature defluorination. Both of these reactions will be studied further as time and personnel become available. The high temperature facilities available from the ordnance project and the new X-ray equipment should be particularly helpful in this work.

Miscellaneous Activities

The minerals laboratory is called on frequently to evaluate bentonite samples both from individuals and operating companies and has been of considerable assistance to the smaller independent producing companies. Additional work should be done on the lower grade bentonites of the state so that Wyoming may maintain its present position as a leading producer of bentonites.

Among relatively short time investigations undertaken, the following should be briefly noted:

Iron ore schists occur in southern Fremont County, where privately sponsored geological investigation indicates a large tonnage of iron ore which can be readily beneficiated. The program has been taken over for extended and detailed prospecting by a private company and evidence to date indicates that the deposits will become a large source of high grade iron ore in the future.

Sulfur deposits in Park County were studied during prospecting by a private company and beneficiation tests were quite favorable.

Cordierite deposits in Albany County were the source of raw material for ceramic tests. The product had satisfactory ceramic properties but was not suitable for the usual white ceramic products of industry.

Clays and shales from Albany and Carbon Counties have been calcined for production of light weight aggregate. Testing of concrete produced with this aggregate was conducted by the Civil Engineering Department

Analcime, a natural zeolite from Fremont County, was tested for use in water softening and found to be about equivalent to natural greensand.

Some titanium-bearing rocks from Albany and Hot Springs Counties have been studied for titanium recovery. Further investigation is indicated.

The Institute-operated assay and analytical service together with a mineral identification service for the people of the state has grown substantially. This has been widely used and advice is given to people interested in the value of mineral commodities. Laboratory apparatus has been added during the last ten years to help in this phase of activity as well as in the prosecution of current research at the Institute. Among this equipment are:

X-ray diffraction unit for mineral and crystal identification together with file of X-ray data.
Spectrometer and spectrograph for detection of chemical elements.
Differential thermal analysis equipment for mineral study and identification.
Spectrophotometer for chemical determinations.
High temperature furnaces.

Civil Engineering Testing Laboratory Research

A research program jointly sponsored by the National Science Foundation and the University of Wyoming on "The Application of Nuclear Radiations to Engineering Materials" was concluded this year. Gamma rays from Co^{60} and neutrons from RaDBe were used to study soil densities, soil moisture content and bituminous content of asphalt mixtures.

Soil Densities. The density of the soil was found by the different absorption of gamma rays with the denser materials absorbing more of the nuclear particles. The researcher found that the different fractions of the soil would have to be separated in order to attain the same accuracy as do normal laboratory procedures. Other researchers in this field found that densities of the whole soil fractions were not as precise determined by this method as by regular laboratory procedures. They used the backscatter technique, which was replaced by the absortpion technique because of better reproducibility of results.

Soil Moisture Content. Moisture content was found by measurement of slow or thermal neutrons. The fast neutrons given off by the RaDBe were slowed down by giving up energy to the nuclei of the hydrogen atom. The water in the soil provided the hydrogen atoms for the production of the thermal neutrons. In the laboratory the soil in a "dry" condition was subjected to the fast neutrons for the background count.

The results of this research were not as accurate as those obtained by the regular method of moisture content now used in laboratory procedures. More work is contemplated to correlate the compatibility of these techniques.

Bitumen Content. Since asphalts are hydrocarbons, they have hydrogen atoms present for the production of thermal neutrons. The absorption method was again used in this research. The results of this new method of bitumen content determination were as reliable as the present-day methods, as well as being faster and more easily obtained.

Miscellaneous Research. Other problems that have been under investigation during the year have been in the field of concrete. The study concrete and concrete aggregates, thermal compatibility and the reactivity of the aggregates has been carried on as well as non-destructive concrete testing by the wave velocity technique.

The thermal compatible studies have been augmented by the addition of an automatic freeze-thaw machine and the addition of automatic controls for the 40° F. to 120° F. equipment. More tests have to be made before a final report can be made, but it seems to be apparent that some aggregates react unfavorably to changes of temperature.

The Rocky Mountain region is notorious for its reactive aggregates. The challenge in this field is the finding of Wyoming reactive aggregates and methods of creating a sound concrete from these aggregates.

The development of the new wave velocity equipment has advanced to a point where the "elastiscope" has been in operation for the past six weeks. More research is needed and has been financially aided by a grant-in-aid from the research council of the graduate school of the University of Wyoming. This "elastiscope" will replace the soniscope, which costs some eighty times as much.

The final research which has just been started is the problem concerning the effect of sulfate on concrete. This research will be sponsored by the Intermountain Chemical Company of Green River, Wyoming.

COAL RESEARCH

Ten years ago coal production was at its all time high in Wyoming and since then has declined gradually to less than one-third of its former level. In the intervening years, water power has increased greatly, gas consumption has replaced coal as domestic fuel, and diesel fuel has replaced coal for locomotive power. Similar trends have prevailed over the nation.

As the coal industry in Wyoming is potentially of immense importance to the economy of the state, coal research has been given a good deal of attention at N.R.R.I. It has been attached in two ways. First, attention has been paid to special local problems, and possibilities for new uses have been investigated. Second, regard has been given to research of a more fundamental nature, and to problems of coal generally.

Bulletin No. 1, issued May, 1946, is a fundamental study of the products of carbonization which can be derived from a number of Wyoming coals.

In 1949, a comprehensive study on the coal resources of the state was undertaken and was carried on for about two years, listing every known coal bed, and past and present operations. Much information has since been given to active and prospective operators based on this survey.

Extending over a number of years, considerable work was carried out on briquetting Wyoming coals. Bulletin No. 3, describing part of the work appeared in November, 1949, and Bulletin No. 5 was issued in December, 1951. In the latter publication special attention was given to

fluidized drying prior to briquetting, a comparatively recent procedure, promising notable economies.

In order to further interest in cokes and chars for metallurgical purposes, considerable work has been done in several directions. Coking coals in the southwestern part of the state were investigated and studied for possible processing or blending. A charring study was undertaken on a number of Wyoming coals to determine char quality and yield. A theory on the coking quality of coal was developed, emphasizing the significance of the molecular weight of the colloidal coal structure. Findings were reported in 1952 before the American Chemical Society.

In considering results of work at the Institute, and also work on similar subjects elsewhere, it appeared that the problem of coal utilization could hardly be solved without proper utilization of every single product derived in processing the coal. Detailed studies are needed to investigate these individual products. Only by weaving the results of a number of such investigations into the proper economic pattern can it be possible to arrive at a profitable operation.

In line with this train of thought an investigation was undertaken in 1954 to fractionate the products of carbonization of coal obtained from a number of Wyoming mines. It was found that a certain portion of the volatile matter can be directly recovered as synthesis gas. In consequence, a small pilot plant was built to demonstrate such production on a continuous basis. In this pilot plant, liquid products as well as a variety of chars can also be recovered, and are now being investigated.

In connection with this program several outlets for char are being considered, and a study is in progress to process chars produced into activated carbon.

Considerable time is spent on special projects sponsored by industry or private interests.

Much work remains to be done, but there is good reason to view the future of coal with a certain amount of optimism. Further increases in power demand will have to be met largely through the use of coal. A very large consumer of power is realizing this situation, and is considering Wyoming as the site for a large processing plant. The facilities of the Institute are being utilized in this survey. Processing coal for liquid fuels and chemicals can only progress slowly, but such development certainly is on the way, and the Institute is actively taking a certain amount of the immense volume of research required to bring this development to fulfillment. This work consists mainly in fundamental research and the acquirement of technical know-how, knowledge which must be ready when future economic conditions warrant commercial development.

PETROLEUM RESEARCH

The Institute has long been interested in the black crude oils produced in this state. It was early recognized that up-grading these oils is desirable as a service to the petroleum industry of Wyoming. The oil industry is the largest industry in the state and Wyoming has become the sixth ranking state in the production of crude oil. In 1949 the Institute was enabled to initiate a research program in petroleum. The outstanding problems confronting the industry in regard to the black oils are the high sulfur content and the high asphalt content of these oils which makes them difficult to process and produce higher grade products by ordinary refining methods.

In order to be of service to the petroleum industry of Wyoming a research program was inaugerated starting July 1, 1950, with the object of finding ways and means for removing sulfur from these oils with possible elemental sulfur as a by-product and at the same time improving the quality of products obtained by refining, thus increasing the use of the black oils. A joint project with the Vaca Oil Exploration Company of California, and the Curran Carbonizing and Engineering Company of St. Louis, was set up for the purpose of investigating the use of sodium hydride in effecting removal of sulfur from black oils. The reactions carried out in this laboratory showed that a high reduction in sulfur content could be effected with sodium and other metallic hydrides. However, the reaction occurred only with excessive quantities of the hydride which proved to be uneconomical.

A comprehensive survey of the literature relating to desulfurization of petroleum products was undertaken and published by the Institute as Bulletin No. 4. The bulletin contains abstracts of 416 journal articles and 961 patents concerning petroleum desulfurization with a numerical patent index by countries and a subject index. This bulletin is the only useful accumulation of this literature that has been published to date.

Hydrohalogenation, that is reacting the high sulfur oils with hydrogen fluoride and hydrogen chloride gas, received attention and experimentation. Up to seventy percent of the sulfur was removed by these reactions. However, the sulfur compounds in this method of treatment are precipitated as sulfonium salts, and the large quantities of material removed by this salt formation amounted to twenty to thirty percent of heavy black oils. The method was abandoned because of the high losses of materials removed.

Since March, 1954, high-pressure hydrogenation has been followed with considerable success not only as a means of sulfur removal but as a possible means for converting heavy asphaltic materials into low boiling compounds of high market value such as liquid fuels and chemicals. A Hamilton Dome crude oil of high specific gravity and an Oregon Basin crude oil of medium-low specific gravity have been used as starting materials for these hydrogenation investigations. After pressure hydrogenation the naphtha fraction distilling below 205° C was found to contain quantities of aromatic compounds that varied with the pressure employed. With reaction pressures above 4000 p.s.i.g. naphtha fractions were obtained distilling from 50 to 60 percent of the untreated oil and containing up to 47.1 percent aromatic material. These naphtha fractions all contained less than 0.05 percent sulfur with an average sulfur content of 0.015 percent.

These experimental results in the hydrogenation of black oils are interpreted as a feasible method for obtaining aromatic chemicals from these oils. The non-aromatic portions of the naphthas appear to contain considerable quantities of saturated and olefinic naphthenes which may be converted to aromatic compounds by means of an aromatizing reaction as in many types of reforming processes regularly carried out by petroleum refiners.

Work is being continued in the laboratory for the purpose of separating and identifying those aromatic compounds which are used in the chemical synthesis industry. The compounds of high market demand and high value are:

Benzene
Toluene
Xylenes
Cumene
Naphthalene
Methylcumenes
Tetralin
Ethylbenzene
Styrene
Cymene

A paper on hydrogenation research on the black oils has been submitted to one of the petroleum journals for publication in the near future.

APPENDIX I

COMPANIES SPONSORING RESEARCH OR TESTS AT NATURAL RESOURCES RESEARCH INSTITUTE

Amalgamated Sugar Company, Ogden, Utah
Benton Clay Company, Casper, Wyoming
Big Horn Coal Company, Sheridan, Wyoming
Black Hills Power and Light Company, Rapid City, South Dakota
Central Farmers Fertilizer Company, Soda Springs, Idaho
Chicago and North Western Railway Company, Chicago, Illinois
Colony Coal Company, Rock Springs, Wyoming
Combined Metals Reduction Company, Salt Lake City, Utah
Continental Sulphur and Phosphate Company, Dallas, Texas
Curran Carbonizing and Engineering Company, St. Louis, Missouri
General Services Administration, Denver, Colorado
General Sulfur Corporation, Dallas, Texas
Hoberg Paper Mills, Green Bay, Wisconsin
Husky Oil Company, Cody, Wyoming
International Minerals and Chemicals Company, Belle Fouche, South Dakota
Kananaske's Development and Mining Company, Nordegg, Alberta, Canada
Kemmerer Coal Company, Frontier, Wyoming
Kingsford Chemical Company, Iron Mountain, Michigan
Mikolite Mining and Development Company, Encampment, Wyoming
Monolith Portland Midwest Company, Laramie, Wyoming
Nugget Coal and Timber Company, Denver, Colorado
Phosphate Fertilizer, Inc., Kemmerer, Wyoming
Phosphate Mines, Kemmerer, Wyoming
Pierce Management Company, Scranton, Pennsylvania
Reiss Briquetting Company, Green Bay, Wisconsin
Reynolds Metals Company, Buffalo, Wyoming
J. R. Simplot Company, Boise, Idaho
South Dakota Natural Resources Commission, Pierre, South Dakota
Sugar Research Foundation, New York, New York
Sulphite Pulp Manufacturers League, Appleton, Wisconsin
Union Pacific Coal Company, Rock Springs, Wyoming
United Clay Products Company, Rock River, Wyoming
United Engineers and Constructors, Inc., Philadelphia, Pennsylvania
United States Army, Office of Ordnance Research, San Francisco, California
United States Bureau of Mines, Denver, Colorado
United States Department of Commerce, I.R.D.D., Washington, D. C.
Vaca Oil Exploration Company, Oxnard, California
Victor Chemical Company, Chicago, Illinois

W98
1957/58

FOURTEENTH ANNUAL REPORT

JUNE 1958

NATURAL RESOURCES
RESEARCH INSTITUTE

THE LIBRARY OF THE
JAN 9 1963
UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING

The University of Wyoming

Laramie, Wyoming

333.7
W99
1957/58

The Natural Resources Research Institute was organized as a department of the University of Wyoming following an appropriation by the State Legislature for its establishment in 1943, and in 1949 became the Engineering Experiment Station of the University.

The object of the Institute is to aid in the development of the natural resources of the State and to promote its industrial growth and the wider utilization of the minerals, fuels, and other resources through laboratory investigations and research upon these resources. The research carried on by the Institute is therefore concerned primarily with problems relating to production, benefication, processing, and application of the State's resources for industrial or consumer uses.

Although the Institute maintains completely equipped laboratories and a full-time staff, the research facilities of the University proper are available to the Research Institute, as are the services of University faculty members in a consulting and advisory capacity.

The Institute cooperates fully with other state, federal, and private agencies in the solution of problems of a scientific or industrial nature and may enter into contractual arrangements with corporations or individuals to carry on sponsored investigations or researches, particularly those that may be of possible future benefit to the State.

1957-1958

TABLE OF CONTENTS

EXECUTIVE COMMITTEE AND STAFF 1

SUMMARY 2

PERSONNEL 3

RESEARCH ACTIVITIES

COAL 4

Primary Tars 5

Chars (Synthetic Coke) 8

Activated Carbon 9

Coal Grindability 10

NONMETALS 12

Phosphate Bulletin 12

Phosphatic Shale 13

Bentonite 13

COOPERATIVE PROJECTS 15

Mineral Matter in Wool 15

Composition of Urinary Calculi 16

ANALYTICAL SERVICES 17

MISCELLANEOUS 23

IMPROVEMENTS IN FACILITIES 25

EXECUTIVE COMMITTEE

H. T. Person, Chairman
G. D. Humphrey, Ex Officio
H. D. Thomas
A. J. McGaw
R. A. Morgan
H. G. Fisk, Secretary

STAFF

Henry G. Fisk	Director
Walter E. Duncan	Chemical Engineer
Ralph D. Law	Petroleum Chemist
Edward Prostel	Coal Research Engineer
Neal Rice	Coal Research Chemist
Carter H. Trimble	Analytical Chemist
Raymond A. Morgan	(Part Time) Head, General Engineering
Elvis A. Hunter	Spectrographic Technician
Oren F. Neal	Mechanic

Roger T. Bush	Laboratory Assistant
Thomas M. Colson	Laboratory Assistant
Uve. H. Dahl	Laboratory Assistant
Ralph M. Iorio	Laboratory Assistant
Arnold P. Jacobson	Laboratory Assistant
Mo Fadel Karame	Laboratory Assistant
Charles C. Messer	Laboratory Assistant
Ralph C. Peterson	Laboratory Assistant
C. Norman Rhodine	Laboratory Assistant
Christie A. Stites	Laboratory Assistant
Joseph R. Tynsky	Laboratory Assistant
Rodney L. Winterbottom	Laboratory Assistant

Marcia Pratt (Mrs.)	Secretary
Nancy Ann Israel	Typist
Sandra Land	Clerk-Typist
Judith A. Snow	Steno-Typist

SUMMARY

During the year 1957-58 major activities in the Institute were directed toward work on fuels and nonmetallic mineral investigations.

Basic research on the processing and characterization of primary subbituminous coal tars was in progress and a continuous hydrogenating pilot plant for grading up primary coal tars was under construction. This work is jointly sponsored by:

The Wyoming Natural Resource Board
Black Hills Power and Light Company
Husky Oil Company
Kemmerer Coal Company
Pacific Power and Light Company
Union Pacific Coal Company

Contract work had to do with preparation of special chars or coke substitutes, and studies of the mineralogical character of phosphatic shales.

Bentonite investigations were in progress in the interests of three companies.

Research investigations in the mineral composition of wool and associated material from sheep fleeces as well as the chemical nature of bovine and ovine urinary calculi were continued cooperatively with the wool department and the department of veterinary science and bacteriology of the College of Agriculture.

Important additions to equipment and facilities include acquisition of a new petrographic microscope, additional laboratory platinum ware, a flame photometer and alteration of the refractometer to increase its range.

PERSONNEL

During July 1957, Dr. Katsuya Inouye completed a ten month Fulbright research assignment at the Natural Resources Research Institute and joined the staff at the Pennsylvania State University.

At the end of July Mr. Nelson McKaig, Jr. resigned as analytical chemist to accept a teaching position at the St. Petersburg, Florida, Junior College.

Mrs. Barbara Moore resigned as spectrographic technician late in July.

Mrs. Nellie Hay resigned as secretary of Natural Resources Research Institute in October.

Appointments were as follows:

Mr. Elvis Hunter, spectrographer, August 1.
Mr. Carter H. Trimble, analytical chemist, September 20.
Mrs. Marcia Pratt, secretary, October 7.

COAL

Wider use of coal potentially the most important mineral resource (except water) in the state presents a major problem in industrial development. Consequently a substantial portion of the work of the Institute continues to be directed toward coal. This work has been carried on both through fundamental or long range research, largely sponsored by the University through the Institute, and the applied or industrial approach through projects sponsored cooperatively by the Wyoming Natural Resource Board and industry.

For many years it has been realized that to burn coal in its raw form as fuel for heat or power is wasteful. A great deal of work throughout the nation and the world has been and continues to be carried out on processing noncoking coals so as to more efficiently utilize them. Low temperature carbonization whereby char and tars are produced from noncoking coals has long absorbed the interest and effort of private and governmental research organizations. Low temperature coal carbonization is beyond the experimental stage in several installations but much work remains to be done in this field. Many of the proposals for low temperature carbonization have neglected full utilization of both the chars and the tars. Economically successful processing operations must make efficient use of both. In the work at the Institute this important fact has been recognized and consequently research is carried on in the two fields. Power plant consumption of char offers the largest potential for this product of a carbonizing operation, and could make available substantial quantities of primary tars. These tars are potentially

valuable as source material for liquid fuels and aromatic chemicals and it is in this field that much of the active research at The Natural Resources Research Institute is in progress. Production of chars for metallurgical use, which would command a premium price over char for a power plant, also offer an added incentive for low temperature coal carbonization, and considerable interest attaches to production of such chars. Much of the past years work of the Institute on special chars had been carried on under contract for private interests.

The other important segment of coal carbonization work has been concerned with the tars. When it is realized that as much as 20 to 40 gallons of tar may be recovered from a ton of coal during carbonization the importance of marketing this tar is evident. Unfortunately, the primary tars produced in the low temperature carbonization of coal differ markedly from the tars and oils derived from by-product coke ovens and markets for these primary tars do not exist at present. However, these tars can be altered materially through hydrogenation to produce fluid lower boiling mixtures high in aromatic content, which offer considerable promise as oil refinery feed stocks and sources of organic chemicals,

Work of the Institute over the past several years has been concerned with hydrogenating low temperature tar fractions and with a study of the products of hydrogenation.

Primary Tars

Hydrogenated coal tar has been fractionated into several hundred cuts of short boiling range. These cuts will be examined to determine

their specific chemical characteristics with a view toward identification of the chemical compounds contained in the fractions.

The major effort of the past year has however, been directed to construction and erection of a continuous coal tar hydrogenation pilot plant and its satellite facilities.

The hydrogenation plant has been designed to provide the utmost flexibility in investigating the conditions for reacting any carbonaceous material that can be handled by pump. The reaction pressure may be made to vary from atmospheric to 6,000 pounds per square inch; the temperature may vary from room temperature to 1,100°F, and the rate of oil feed flow may be adjusted anywhere between 0 and 1.2 gallons per hour. With the flexibility provided by the instrumentation and design, it is thought that this plant will be an ideal research instrument that can provide much information concerning reaction temperatures, reaction time, hydrogen/oil ratios, oil/catalyst ratios, etc. Such information is necessary to prepare for a commercial process in the utilization of primary tars and oils.

The hydrogen compression unit is composed of a compression cylinder into which distilled water will be pumped to force hydrogen into the accumulators under pressures up to 5,000 pounds per square inch. The accumulators are so connected that each cylinder may be used independently or in series in a pressure line. The cylinders may also be used, either independently or in series, as a supply of high pressure hydrogen for pumping into the high pressure hydrogenation plant. These accumulators are also connected with the batch process, high pressure apparatus in a pressurized line that can furnish hydrogen to the reactor at any time and at pressures up to 5,000 pounds per square

inch. It is planned to finish a third accumulator during the summer and another compression cylinder will be added to the plant at the same time. The addition of these two cylinders will double the length of time that hydrogen may be pumped to the hydrogenation plant over the three cylinders now installed. The two cylinders have been in the fabricating shops for sometime and will be completed in a few months.

The system needs a high pressure, 2-way pump to put the plant in operation, together with the necessary wiring to operate the pump motor. As this report is written it is learned that the Natural Resource Board has generously appropriated sufficient funds to complete construction of the pilot plant.

A battery of eight high efficiency stills was added to the distillation equipment during the past year. These stills have columns packed with stainless steel helixes that provide for columnar efficiencies ranging from 100 to 240 theoretical plates and can provide short boiling range cuts of chemical compounds of 90 to 96 percent purity. At the time the above stills were installed, the older battery of stills was repacked with the same type Podbielniak helixes as the battery of eight new stills. The combination of the new and old stills provides a total of twelve high efficiency stills that can handle a great deal of materials and provide basic information concerning the chemical character of the cuts obtained in a relatively short period of time. Nine of the stills have been in operation since January, 1958.

During 1956 a stainless steel primary fractionator was built and put into operation. This still is used to provide cuts of the synthetic, hydrogenated oil such as naphthas, distillate and gas oils from which

gasoline and diesel fuels may be made. This fractionating still has a column packed with stainless steel lathe turnings and has a high separation factor for a primary still. The apparatus was built from stainless steel supplied by the Carpenter Steel Company.

The high pressure reaction plant is now about 90% complete. The high pressure vessels were fabricated during the summer and fall, and were installed within the steel barrier during the winter and spring months. The necessary tubing connections uniting the preheater, reactor, hot liquid-vapor separator, and the cold liquid-vapor separator have been made. Pressure gages, liquid level indicators, control valves, and temperature control instruments have been installed and many of the connections with the reaction system have been made.

The wiring to the heating elements, the pump motor, and to the temperature control instruments remains to be done. A highly corrosive resistant high pressure pump has been connected into the reaction system and will be used to pump the tars and oils through the reaction system. This pump was purchased by the Institute from funds provided in part by the Research Council of the University.

Chars (Synthetic Coke)

An investigation of the physical and chemical properties of chars prepared from Wyoming subbituminous coals, was completed and a paper reporting the results of the study under authorship of Dr. Katsuya Inouye, Mr. Neal Rice, and Mr. Edward Prostel is in preparation.

In a sponsored project possibilities of making synthetic coke from char produced by the fluidized system of charring were investigated. Certain characteristics of this type of char made it impossible to

produce coke-like product of satisfactory quality. Good synthetic coke was produced from char made in the Institute laboratory, and it is believed that a synthetic coke acceptable to the phosphorus industry could be made from char produced in a Lurgi retort or other suitable process. Sponsorship of this work although quite promising was terminated. It is planned to continue it as an Institute project as time permits.

In another phase of the synthetic coke work combinations of low volatile char and phosphate rock fines or slimes have been briquetted with the idea of introducing the reducing char in this form. Phosphatic shale from Idaho lends itself to forming better char-phosphate briquets than does Montana phosphate rock, because of the sandy nature of the latter. However, possibilities of overcoming the less satisfactory briquetting behavior of the Montana phosphate rock are under investigation.

Activated Carbon

Research on this project included preparation of water treating carbon in a batch retort wherein carbonization was followed by steam activation in the same retort without cool down between the two steps.

Carbons produced in this manner appear to drop off in phenol adsorption with exposure to air. Plans to overcome this fault involve an after treatment with hydrogen-nitrogen mixtures. Thus it is hoped to remove the offending oxygen which it is thought occupies bonds to which phenol groups would otherwise have access.

A study of the literature reveals that treatment of certain other carbons by mixtures of hydrogen and nitrogen has been successful.

Heats of wetting have been determined in a calorimeter built here following general plans of a machine designed by Griffith and Hirst of the British Coal Utilization Board, and described in "The Ultrafine Structure of Coals and Cokes", London 1944. This information is of basic nature and shows heats of wetting of the order of 24 cal/gram, and surface areas of 200 to 300 M^2/gram. A proposal is planned to the National Science Foundation requesting funds to do similar work on coals, cokes and activated carbons.

Other properties of the activated carbons studied and determined are specific gravity by mercury displacement and specific gravity by methanol displacement. The difference between these two figures on a given sample tells us percentage of free space or total voids as so measured.

Iodine number, methelene blue number and molasses number indicate relative size of pores or voids. A complete spectrum of these tests will show clearly what portion of the pores are available to molecules of decreasing size thus isotherms may be drawn showing pore size distribution. From molasses which will enter pores of about 200°A to methanol which has a molecular diameter in the order of 5A° we have a measure of pore sizes in that range.

Coal Grindability

The relative grindability of coal is important in its use as power plant fuel. The moisture content of a coal was believed to effect grindability. Grindability test equipment was introduced and the grindabilities of several coals of varying moisture content have been investigated. Of the coals examined only the lower rank coal from

northern Wyoming has shown a significant change in grindability with change in moisture. Other lower rank coals and lignites will also be tested to determine whether definite trends can be found.

NONMETALS

Phosphate Bulletin

Bulletin 6 reporting results of the phosphate investigations on the Lander phosphate rock over the past several years was published in September, 1957. One thousand copies of the bulletin were printed and about half of this number have been distributed to persons on the Institute mailing list and others requesting copies as a result of announcements in the technical press. The work covered in the Bulletin is summarized as follows:

"The major portion of the testing was devoted to work on rock from the Twin Creeks area and it has been shown that between 40 and 50% of the calcite present in the rock can be eliminated by calcination and slaking procedures.

Melted defluorinated phosphate of fertilizer grade was made in a cupola and feed grade phosphate was produced by sintering in a small rotary kiln. Studies on defluorination by melting in the small rotary kiln demonstrated the possibility of producing a low-fluorine product. However, kiln design should be adapted to this process in order to overcome ring formation toward the feed end of the kiln.

Economic studies show the marginal character of the rock when considered for conventional phosphate processing. The major reason for this is the low analysis of the material as mined, since three tons of rock must be mined to obtain P_2O_5 equivalent to two tons of standard, +30% rock. The rock is about as high in P_2O_5 content as phosphatic feed to electric furnaces presently operating in Idaho and Montana. It would represent higher cost raw material for an electric furnace

operation because of the higher mining costs involved in its production (main reserves must be mined by underground methods) and due to the presence of excess lime in the form of calcite which must be fluxed with added silica."

Although economics for development of the Lander phosphate deposits were not attractive at the time the studies in Bulletin 6 were made, it should be pointed out that economic conditions are continually changing, and that the situation may improve as costs of electric power decrease, or as supplement materials or reagents required in processing become obtainable at lower cost in a given area. For example the potential availability of sulfuric acid in central Wyoming should have a favorable influence on cost of manufacture of superphosphate and concentrated superphosphate in the state. Growing markets for phosphate fertilizer in an area which would be served by a fertilizer plant in central Wyoming also may favor reappraisal of a local fertilizer industry utilizing these phosphate deposits.

Phosphatic shale

A mineralogical investigation of Idaho phosphatic shale was carried on under private sponsorship during the past year. Samples of several grades of rock were disintegrated in slurry form and fractionated in the sub-sieve size range. The fractions obtained were submitted to X-ray diffraction, chemical analysis and differential thermal analysis studies.

Bentonite

If Wyoming is to maintain its position in the bentonite industry research on grading up or purifying low-grade bentonites must be under-

taken. Furthermore, a better understanding of the base exchange characteristics and other fundamental clay properties of montmorillonite and other clay minerals must be had. Some work in these fields has been in progress. More use needs to be made of modern methods for clay research. Improved techniques for X-ray examination of clay minerals have been under study during the last several months. This work coupled with base exchange tests and thermal differential analysis should lead to a better knowledge of the basic nature of bentonite, and to the possible modification of bentonites for its several applications.

Bentonite work undertaken for private interests during the past year has involved an investigation on the upgrading of impure bentonite and critical examination of bentonites of differing physical properties. For this latter work bentonite samples are undergoing complete physical, chemical, and mineralogical tests and evaluation.

COOPERATIVE PROJECTS

Mineral Matter in Wool

Work on the U. S. Department of Agriculture wool project,* carried on jointly by the Wool Department and Natural Resources Research Institut was continued. A total of 50 wool fleeces have been under investigation. In addition there are six tag samples and 24 samples contrasting tip-end versus basal-end of each the shoulder and breech from six fleeces which are part of the original fifty fleeces. Wet ashing of samples followed by spectrographic analysis of the ash samples obtained has been carried out as cleaned wool samples have been received.

During the course of this work the following procedures have evolved for spectrographic and chemical analysis of trace elements and those major elements to be reported by Natural Resources Research Institute.

On wool ash samples two separate spectra are taken, one on the ash without dilution for minor elements, and a second on which the ash is diluted 1 to 9 with zinc oxide for major elements. Minor elements are determined by comparison of intensities of spectral lines of the elements sought with known percentages of the same element in a major element base. Major elements are determined on the film obtained from the zinc oxide diluted sample. Line intensities of these elements are then compared with major element standards prepared in a zinc oxide base. Trace elements in suint and grease are also determined spectrographically

Minor or trace elements are determined spectrographically on wool dirt as in the case of the wool ash. Major elements are, however, determined by conventional wet methods of analysis.

* Title--Study of the chemical composition of wool with regard to minor elements in relation to the origin of the wool, commercial values and fundamental properties.

Alkalis (sodium and potassium) are determined by the flame photometer in all samples because sensitive lines of these elements do not appear in the region spectrographed.

Composition of Urinary Calculi

A problem of importance in animal production and veterinary science has to do with the formation and control of bovine and ovine urinary calculi. Apparently calculi from various sources and causes may vary considerably in composition or makeup, and some of the older reports seem to be questionable as to the chemical nature of livestock calculi. The Institute has cooperated with the department of veterinary science and bacteriology in an investigation of the chemical composition of over one hundred urinary calculi from cattle and sheep. Major and minor elements are determined spectrographically by the methods outlined for wool, in a previous section of the report, except that generall the calculi have been spectrographed directly without previous ashing. Heating the sample in the graphite electrode was usually necessary prior to arcing to prevent bursting out of the charge. Alkalis were determined by means of the flame photometer. The work has nearly been completed and is expected to be published jointly.

ANALYTICAL SERVICES

The analytical laboratory performs a vital service both to the Institute and to individuals or groups who are exploring or developing the mineral resources of Wyoming. During the period July 1, 1957 through June 30, 1958 (June 1958 estimated) 2,220 analysis, test and assays were made by the analytical laboratory. This does not include a large number of X-ray analyses, emission spectrographic and X-ray spectrographic analyses which have been made as a part of the nonmetals investigations in progress. The accompanying Table, Parts A, B, C, and D, tabulates analyses made in the analytical laboratory during the year.

Table Part A

This portion of the table represents, primarily, individually submitted ore and mineral samples. Rather roughly speaking, this section indicates the interests of the individual prospector in Wyoming. Overall, the list also indicates the rather wide interests in the various elements by the individuals concerned, and as may be seen by referring, to the table, these interests are widely diversified.

Comparison of this section of the table with the corresponding section of last year's report shows several changes. The total number of analyses is down, (228 analyses compared to 430 last year). Interest in uranium has increased (70 analyses compared to 29); maintaining last year's trend. The number of titanium analyses performed dropped from 139 for last year to only 5 for this year. Gold and silver analyses are about the same, however, interest in platinum has increased remarkably,

With industry using more of the rarer metals, demand for niobium has increased considerably in the past few years. This demand is shown to a certain extent not only by the number of niobium analyses, but also by the large number of individuals wanting information on properties and characteristics of niobium bearing ores and minerals.

Table Part B

The number of complete analyses performed for major and some minor constituents has increased by more than 20% in the last year. The material types submitted has also been more varied. The fluorspar analyses were made under contract with the U. S. General Services Administration to determine acceptability of the material as part of their stockpiling program of strategic materials. This contract was awarded to another laboratory January 1, 1958, and the work is no longer done by the Institute laboratory.

The wool dirts were submitted for analyses when spectrographic results were shown to be unsatisfactory for the major constituents.

Of the remainder of this group, the bentonites constitute a special project of the institute to attempt to correlate physical properties with certain of the constituents present. The activated carbon ashes were also done in connection with current Institute research.

Table Part C

Of this section of the table, the urinary calculi and exchangeable cation extracts are of special interest. The urinary calculi were submitted for a determination of their sodium and potassium content with a further determination of the phosphorus content of certain selected samples of this set. The exchangeable cation extracts were submitted

for sodium and potassium determinations as a part of the special bentonite project referred to above.

As a matter of interest, sodium and potassium determinations by classical gravimetric procedures are laborious and time consuming. The large number of samples to be analysed (170) could not have been completed in a reasonable time had it not been for the recent acquisitio of a flame photometer.

Table Part D

This section covers those samples of bentonite received for physical tests. The various physical properties of individual bentonites determines the ultimate use of the clay, whether it is satisfactory for oil well drilling mud, suitable as a binder in foundry mold sand or other purpose. These samples are in addition to current institu projects on bentonites.

Table I

Analyses Performed by Analytical Laboratory
NRRI

Fiscal Year 1957-58

Part A

Individual Elements

Beryllium	2	Phosphorus	1	Vanadium	1
Calcium	9	Platinum group	24	Uranium (chemical)	27
Chloride	3	Potassium	2	Uranium-fluorometric	43
Copper	6	Selenium	2	Zinc	1
Gold	34	Silica	3		
Iron	12	Silver	34		
Magnesium	5	Sodium	4		
Niobium	2	Sulfate	5		
				Total analyses	228
				Representing 193 samples	

Part B

Complete Analyses

Type Sample	No. of Samples	No. of Analyses
Fluorospar	44	352
Wool Dirts	50	510
Phosphate Rock	2	18
Granite Rocks	5	68
Bentonite Clay	7	109
Activated Carbon Ash	13	143
Total	121	1,200

Part C

Special and Miscellaneous Analyses

	No. Samples	No. Analyses
Coal, for BTU, sulfur and proximate	17	102
Coal, BTU and sulfur only	25	50
Activated Carbon, ash and volatile	2	4
Exchangeable Cation Extracts		
(a) Sodium only	33	33
(b) Sodium, potassium, calcium	30	90
Urinary Calculi, alkali metals & phosphorus	142	334
Total	249	613

Part D

Physical Tests of Clay

Colloidal Content	43
Colloidal Properties	46
Bonding Strength	37
Permeability	31
Yield Data	22
Total Represents 46 samples	179

Total Samples listed	609
Total Analyses listed	2,220

Platinum laboratory ware acquired during the year includes 3 - 50 milliliter dishes, 2 crucible covers, and 1 perforated filter conc. Two older crucibles were returned in exchange for the new platinum ware.

The distilled water requirements of the Institute laboratories has increased considerably, so the storage capacity from the still was more than doubled. This permits our still to run overnight with no danger of storage overflow.

MISCELLANEOUS

Investigation of a suite of samples of platinum ores from a Wyoming property was made by fire assay and spectrographic methods.

February 17 and 18 the director attended as official delegate, a conference on Engineering Science Research sponsored by the National Science Foundation, at the University of Colorado. A written and oral report were submitted to Dean Person and the Engineering faculty respectively.

At the request of the Natural Resource Board written material on research activities in the state was prepared by the director for a Wyoming issue of Commerce and Industry. The prepared material was printed in various sections of the publication under anonymous authorship.

In August, 1957, the Institute sponsored the fifth biennial briquetting conference of the International Briquetting Association at Glenwood Springs, Colorado. Dean H. T. Person and staff members took part in the program. Association Proceedings were published as Institute Information circular No. 9.

A paper "Primary tars as Refinery Feed Stock" was presented by Dr. Ralph D. Law at the Rocky Mountain Regional Meeting of the Western Petroleum Refiners Association in Casper, September 27, 1957. Dr. Law also presented a paper "New Potentials in Coal Utilization," at the seventh conference of Coal Research, Incorporated at Seattle, Washington, February 28. This paper was reprinted in the proceedings of this organization.

A report on hydrogenating low temperature coal tars to liquid fuels

and chemicals as carried on at the Institute appeared in the October 25, 1957, issue of Petroleum Week.

Mr. Edward Prostel presented a paper "Coal Utilization Work at the University of Wyoming" at the annual meeting of the Rocky Mountain Coal Mining Association in Glenwood Springs, Colorado, June 24, 1957. Mr. Prostel also presented a paper "Briquetting of Phosphate Rock", at the biennial meeting of the International Briquetting Association in Glenwood Springs, August 20.

Mr. Neal Rice, as secretary and program chairman of the International Briquetting Association, arranged the program of the fifth biennial conference and with Mr. Prostel edited the proceedings, which were published as Natural Resources Research Institute Information Circular No. 9.

Bulletin No. 6, "Central Wyoming Phosphate Rock, Character, Processing and Economics", was published in September, 1957 under authorship of Mr. Walter E. Duncan and the director.

IMPROVEMENTS IN FACILITIES

The Bausch and Lomb refractometer was returned to the factory for replacement of the prisms to increase the range of the instrument and adapt it to identification of organic hydrocarbon and aromatic fractions in the petroleum and coal tar processing work.

Through an arrangement with the soils laboratory of the College of Agriculture, a Perkin Elmer flame photometer was purchased and set up for alkali determinations by the flame photometer method.

The differential thermal analysis equipment which had been built some years ago was modified and by introducing a gear driven variac automatic program control was built into the unit.

More adequate gas and fume ventilation was installed in the petroleum laboratory and over a small charring furnace in the coal laboratory.

The Andreason pipette sedimentation technique for fractionating clays or finely suspended mineral matter was introduced and a constant temperature cabinet was built to enclose the pipette.

Office equipment was improved through acquisition of a new typewriter, a later model mimeograph machine and an additional steel file.

Obsolescent equipment, including the cupola in the phosphate pilot plant was removed to increase floor space for current work.

A complete redecorating and "clean up" of laboratories and office took place during the year.

W98
1959/60

SIXTEENTH ANNUAL REPORT

JUNE 1960

NATURAL
RESOURCES
RESEARCH
INSTITUTE

Coal Research
Non-Metallic Mineral Research
Petroleum Research
Mineral Identification
Chemical Analyses

THE LIBRARY OF THE
JAN 9 1963
UNIVERSITY OF ILLINOIS

The University of Wyoming
College of Engineering
Laramie, Wyoming

333.7
W98
1959/60

1959-1960

TABLE OF CONTENTS

Executive Committee and Staff 1

Preface 2

Introduction 3

Summary 4

Special Activities 7

Publications 8

Staff Changes 8

Synthetic Coke Project, Staff 9

Non-Metallic Research, Walter E. Duncan 10

Hydrogenation Research, Ralph D. Law 12

Coal Research, Edward Prostel 15

Determining Properties of Carbons as Practiced at N.R.R.I., Neal Rice 16

Analytical Laboratory, Carter H. Trimble 17

EXECUTIVE COMMITTEE

H. T. Person, Chairman
G. D. Humphrey, Ex Officio
H. D. Thomas
A. J. McGaw
R. A. Morgan
H. G. Fisk, Secretary

STAFF

Henry G. Fisk	Director
Walter E. Duncan	Chemical Engineer
Ralph D. Law	Petroleum Chemist
Edward Prostel	Coal Research Engineer
Neal Rice	Coal Research Chemist
Carter H. Trimble	Analytical Chemist
Elvis A. Hunter	Spectrographic Technician
Oren F. Neal	Mechanic
Lawrence K. Millay	Mechanic
Nancy K. Stumpf	Secretary
Uwe H. Dahl	Laboratory Assistant
Arnold P. Jacobson	Laboratory Assistant
Paul A. Fossey	Laboratory Assistant
Lael H. Hoopes	Laboratory Assistant
James W. Stugart	Laboratory Assistant
Graham D. Sims	Laboratory Assistant
Edward M. Young	Laboratory Assistant
James J. Foy	Laboratory Assistant
Joseph R. Tynsky	Laboratory Assistant
John C. Shaffer	Laboratory Assistant
John E. Knopp	Laboratory Assistant
George Q. Moses	Laboratory Assistant
Irvin G. Bassett	Laboratory Assistant
Lin-Nar Loh	Laboratory Assistant
Julie A. Williams (Part Time)	Typist

PREFACE

The Natural Resources Research Institute was organized as a department of the University of Wyoming following an appropriation by the State Legislature for its establishment in 1943, and in 1949 became the Engineering Experiment Station of the University.

The object of the Institute is to aid in the development of the natural resources of the state and to promote its industrial growth and the wider utilization of the minerals, fuels, and other resources through laboratory investigations and research upon these resources. The research carried on by the Institute is therefore concerned primarily with problems relating to production, beneficiation, processing, and application of the state's resources for industrial or consumer use.

Although the Institute maintains completely equipped laboratories and a full-time staff, the research facilities of the University proper are available to the Research Institute, as are the services of University faculty members in a consulting and advisory capacity.

The Institute cooperates fully with other state, federal, and private agencies in the solution of problems of a scientific or industrial nature and may enter into contractual arrangements with corporations or individuals to carry on sponsored investigations or researches, particularly those that may be of possible future benefit to the state.

INTRODUCTION

In the summer of 1949, through the joint efforts of the Natural Resources Research Institute, the Chicago and North Western Railway Company and the Wyoming Geological Survey, a portion of the iron ore schists, Section 26,T. 30 N., R. 100 W., in the Wind River mountains near Atlantic City, was mapped and systematically sampled. Chemical analyses were made on the samples obtained and assay results and ore reserve figures were compiled. These data and the maps of the area covered were included with an Institute mimeographed report by Mr. Ralph H. King, which was distributed to interested parties.

During 1951, microscopic study and laboratory beneficiation tests made by N.R.R.I. showed that a high grade iron concentrate could be made from these ores, by magnetic separation.

As a result of these preliminary investigations, the J. R. Simplot Company of Boise, Idaho became interested in the Atlantic City iron deposits and through their affiliate, Ruby Company, detailed magnetometer surveys, trenching and drilling were undertaken. Later, the Geneva Steel Company carried on further exploration and extensive laboratory and pilot plant tests. Quite recently, (June 1, 1960)*, Geneva has announced plans to construct a $50,000,000 iron ore processing plant near Atlantic City.

---

* See Denver Post, June 1, 1960; Laramie Daily Boomerang, June 2, 1960.

SUMMARY

Highlights - 1959-1960

During the year under review, there have been initiated, or progressed, a number of outside sponsored projects. The following companies have underwritten these investigations in whole or in part:

Benton Clay Company
Darrell Blanton
Cameron and Jones, Inc.
Husky Oil Company
Pacific Power and Light Company
J. R. Simplot Company
Union Carbide Olefins Company
Union Pacific Railroad Company

In addition, the work on coal tar was supported in a substantial manner by the Wyoming Natural Resource Board.

In January of the current year, a project on synthetic coke was set up under a grant from the Union Pacific Railroad Foundation.

Work in the analytical laboratory almost doubled over the previous year and additional help was required to meet the increased work load. Due to the high quality of the analytical laboratory work, the Institute became a recognized laboratory in the field of rock and mineral analysis.

The sixth biennial briquetting conference sponsored and programmed by N.R.R.I. was held in Glacier Park, August 24, 25, and 26, 1959. The proceedings of this conference were published as N.R.R.I. Information Circular No. 10, December, 1959.

Obsolescent coal pilot plant equipment was removed from the coal building to permit conversion to needed laboratory space. A new Right-A-Weight balance was purchased and installed in the coal laboratory and the ceiling of this room was covered with insulating board. A new electric muffle furnace with automatic temperature control and regulation was purchased for the coal building.

Some additions were made to the foundry sand testing equipment.

Degassing and helium density equipment was built for determining the pore and sub-microscopic pore structures of carbons and chars.

The titanium publication, N.R.R.I. Information Circular No. 7, was reissued in mimeographed form.

Fundamental research continued in the fields of coal, oil and bentonites. That in coal was concerned with preparation of "form cokes" or coke substitutes, determination of the properties of activated carbons or special chars and the conversion of primary or low temperature tars.

The properties of bentonite, especially as affected by "fixed", and extraneous salts or impurities, were under study. A better understanding of the effects of the salts found in bentonite is

needed to more efficiently process and utilize this clay, especially where it occurs in impure form.

An intensive study of phosphate defluorination was undertaken on a sponsored basis for a private concern.

An unprecedented demand for N.R.R.I. Bulletin No. 2, "Bentonite, With Test Methods and Results of Tests of Wyoming Bentonites", issued in 1946, exhausted the remaining copies of this publication, which is now available only on special order in Thermofax form.

An investigation on coal ash was undertaken for private interests.

The Institute briquetting plant was operated on a custom basis, in one case for the briquetting of an oil shale of foreign origin.

An extensive investigation of smokeless briquets was in progress.

As the year closed, (June 30, 1960) testing and evaluation of samples from a large Wyoming placer deposit was under way.

Total receipts for project work and tests were the second largest in the history of N.R.R.I., in favorable contrast to the two previous years, which, due to generally depressed business conditions, were much lower.

SPECIAL ACTIVITIES

August 5 and 6, 1959, the Director visited trona core drilling operations near Green River.

August 30 and 31, 1959, W. E. Duncan made a trip to the Leucite Hills in the interests of a potash inquiry.

August 24 to 26, 1959, Neal Rice, Edward Prostel and the Director attended the sixth biennial briquetting conference of the International Briquetting Association at Glacier Park, Montana. Mr. Rice was re-elected Secretary-Treasurer of the Association. Mr. Prostel presented a paper, "Synthetic Coke from Subbituminous Coal", and also presented the report of the Standards Committee.

September 5 to 11, 1959, W. E. Duncan visited trona drilling operations near Green River.

September 15 and 16, 1959, the Director attended meetings of the American Mining Congress in Denver.

November 18, 1959, the Director attended a meeting at the Bureau of Land Management office in Cheyenne at the request of the Wyoming Natural Resource Board.

December 12 to 17, 1959, W. E. Duncan, at the courtesy of an operating company, visited steel foundries in Detroit and Cleveland in connection with the use of Wyoming bentonite.

February 10, 1960, the Director gave a talk, "A Look at Wyoming's Resources" at the Cheyenne Rotary Club.

February 13 and 14, 1960, the Director attended the annual convention of the A.I.M.E. in New York as Wyoming Mining and Metals Section Delegate.

February 27, 1960, the Director attended the A.I.M.E. Wyoming Mining and Metals Section meeting in Casper and gave the New York delegate's report.

April 28 and 29, 1960, W. E. Duncan attended the Pacific Northwest Metals and Minerals Conference at Portland, Oregon.

June 13 to 17, 1960, Neal Rice attended the Gordon Coal Conference, New Hampton, New Hampshire, and participated with a presentation, "Surface Areas by Means of H.O.W. Determination".

PUBLICATIONS

"Proceedings of the International Briquetting Association (Sixth Biennial Briquetting Conference)", Glacier Park, Montana, N.R.R.I. Information Circular No. 10, December, 1959.

"The Use of Asphalt as Briquet Binder in the United States of America", by Edward Prostel and Neal Rice, Revue de L'Industrie Minerale, January, 1960.

STAFF CHANGES

Toward the end of the fiscal year, the Director, Henry G. Fisk, resigned effective June 30, 1960, to accept a teaching position on the staff of the Montana School of Mines at Butte.

In June of 1960, Elvis A. Hunter resigned, preparatory to entering dental school.

SYNTHETIC COKE PROJECT

Staff

Starting in January, 1960, under a grant from the Union Pacific Railroad Foundation, a study was undertaken on the production of synthetic coke prepared from Wyoming noncoking coal. Based on previous work at N.R.R.I., coal was carbonized at comparatively high temperatures to yield low volatile char, the char was briquetted, and the briquets were recarbonized. Previously it had been found that in such a way a synthetic coke could be produced with strength characteristics comparable to commercial blast furnace coke. Systematic work has now been started to evaluate the various factors entering into the production; as kind of binder used, asphalt or pitch, physical and chemical characteristics of the binder, amount of binder used, briquetting variables, including briquetting pressure and temperature. Details in curing procedure were included, especially time and temperature involved, and recarbonizing temperature. Previous investigations seemed to show that pitch binders were preferable, and especially those of high melting points. Work so far indicated that a good commercial briquetting asphalt is also best suitable for the preparation of synthetic coke.

As a part of the synthetic coke project, considerable time has been devoted to a study of the literature on the measure of the reactivity of carbons and how this can be related to metallurgical reactivity. Chars and synthetic coke-like products produced from Wyoming coal have been found to be lacking when used in some electric furnace processes and an effort is being made to set up equipment which will permit comparison of different carbons under actual electric furnace conditions. This equipment is considerably more complicated and extensive than was visualized when the project was originally set up. On the other hand, such testing seems to be the only way that the differences between such materials can be pointed out short of a large scale test in commercial equipment with its attendant problems of scheduling in a commercial plant and the possibility of loss of production if the test is not a successful one.

Inquiries are being made to electrical equipment manufacturers and furnace suppliers to determine what can be obtained commercially and will not have to be built.

NON-METALLIC RESEARCH

Walter E. Duncan

Bentonite Studies: Considerable effort has been devoted to a study of some of the general properties of the bentonite that has been used as the "standard" with which prospectors and commercial samples of bentonite are compared. It is a high-sodium, swelling type bentonite of the type used for drilling mud work but also has fairly good foundry properties. The work done is both chemical and physical.

The chemical work has involved a detailed chemical analysis and, in addition, some work concerned with ion exchange resins for the study of the ions either adsorbed on the clay particles or present in the clay as an impurity. This last work is only very preliminary in that a great deal of experimental work will be necessary to arrive at satisfactory procedures whereby the resins can become useful tools in the study of clay systems.

The physical activities include the investigation of the dehydration of some coarse particles of the clay. The tests are still in progress and it appears that, as was the case with a similar study of a foundry clay, the clay takes up water from the atmosphere even after heat treatment to fairly high temperature. The samples undergoing hydration will be subjected to diffraction measurement and differential thermal analysis to note the changes in behavior that might be related to the heat treatment and subsequent rehydration. Several attempts have been made to utilize a procedure involving the sorption of ethylene glycol or glycerine onto clay surfaces to arrive at an estimate of the swelling properties of a clay but the procedure appears to need some additional study before the results are meaningful.

The differential thermal apparatus has been modified so that the temperature of the specimen undergoing test will be recorded on the chart which records the differential effect. Some information has been collected on the equipment that will be required to make the differential thermal apparatus more sensitive; thus, detecting the presence of impurities in small quantity and emphasizing the differences between samples.

Some additions have been made to the foundry sand equipment so as to permit measurement of the deformation of the bentonite-bonded sand specimens while these are undergoing test and also to measure the flowability of the clay-sand mixture while it is being rammed.

The bentonite testing has continued on prospector's samples and an occasional sample from a commercial plant. A large number of samples were tested for a group interested in evaluating a bentonite property. A study of some contaminated bentonite was undertaken on a sponsored basis.

Miscellaneous: Some gypsum plaster was made and tested to evaluate the resulting product for comparison with commercial plaster.

Three gabbros containing magnetic mineral were treated and the resulting products evaluated.

Two dune sands were studied with the view of producing sand for use by railroad locomotives. One of the sands contained a large fraction within the specification size range and could be the source of such sand.

Several samples of oxidized lignitic material were tested. This material is finding use as an additive to drilling muds where it is used to control viscosity. The active ingredient appears to be humic acid which, in the natural state, is apparently combined with calcium.

Some coal ash has been studied with the view of finding some way of utilizing it or producing some commercial product from the ash.

A sample of placer gravel has been studied to determine the values present and manner in which these occur so as to determine whether the gravel contains valuable minerals in commercial quantities and how these might best be recovered economically.

HYDROGENATION RESEARCH

Ralph D. Law

During the past fiscal year, a number of tars and black oils were treated in the hydrogenation plant under widely varying process conditions. While the production of liquid fuels received the most consideration, a very considerable amount of time was spent in the production of petrochemicals. The continuous flow hydrogenation plant has proved to be very versatile and flexible in treating the vastly different coal tars, black crude oils and distillates under a great variety of process conditions.

The tars processed in the hydrogenation plant ranged from lignitic tars to bituminous tars with two subbituminous tars in between the two extremes in ranks in coals of origin. The black oils which were processed ranged in gravity from 5° to 23° A.P.I. The oil with the gravity of 5° A.P.I. was a solid at room temperature and had to be heated to about 120°F to pour from the shipping container.

Coal Tar Hydrogenation: The first primary coal tar to be treated was a tar prepared by the Parry carbonization process which is an entrained bed system. The tar contained a considerable quantity of fine solids carry-over which had to be removed because of the clogging of tube lines by the accumulation of the solids in the lines. The tar was prepared from coal from the D. O. Clark mine near Rock Springs, Wyoming and was processed under two sets of hydrogenation. The tar was run under conditions to produce a large yield of diesel fuel with a relatively small yield of gasoline. Yields of up to 70 percent of diesel fuel were found possible under mild conditions of temperature and pressure. The gasoline yields under these conditions were in the vicinity of 15 percent.

Later, more severe conditions were applied with the D. O. Clark Parry process tar which resulted in yields of gasoline as high as 57 percent.

Another tar made from D. O. Clark coal was received and reacted with hydrogen. This second tar was produced by the Lurgi carbonization process. The two tars were almost identical in physical and chemical properties except that the tar made by the Lurgi process contained no solids carry-over and required no special preparation before running through the hydrogenation plant. Processing this tar under the same reaction conditions as the Parry process tar gave almost identical synthetic crude oils from which diesel fuels and gasoline were distilled and similar percentage yields were obtained.

A bituminous tar derived from coal obtained from Pitt seam No. 8, near Institute, West Virginia, was received at the laboratory to be processed into a synthetic crude oil. The bituminous tar was found to be more heat sensitive and caused clogging of the plant after 7 or 8 gallons of tar were pumped through the plant. The oil obtained by hydrogenation of the tar contained a high quantity of aromatics and olefins but was relatively low in phenols. The tar was reacted under conditions that produced good yields of petrochemicals. The off gases were found to contain only trace amounts of gaseous hydrocarbons.

Three lignitic tars were received during the year. One of the tars was made by the modified Lurgi process plant located at Bien Fait, Saskatchewan, Canada, from a lignite coal mined nearby. Another tar was made by the Parry process plant at Rockdale, Texas, from a Texas lignite coal. The third lignite tar was made at the Lurgi process plant at Dickinson, North Dakota from a North Dakota lignite coal. All three tars were very soft, waxy materials that required less dilution for pumping qualities than tars from higher rank coals. From the oils obtained by hydrogenation of the tars, it seemed the lignitic tars are very excellent for producing petrochemicals. The high oxygen content of the tars, provide higher yields of phenols than the tars from higher rank coals. However, the lower quantities of ring structures provide less yields of benzenoid compounds but higher yields of olefins of aliphatic structures. These tars gave fair yields of amines of the pyrrole type. Larger quantities of the three lignite tars have been supplied this laboratory for a continuing investigation in the hydrogen treating for the production of liquid fuels and petrochemicals.

Hydrocracking: A short series of hydrocrack runs were made on heavy gas oils produced from three Wyoming black oils. The first of the oils used was a black oil from the Horse Creek field; the second oil was an Oregon Basin black oil; and, the third oil was from the Red Springs field. The Red Springs oil had a gravity of 5.0° A.P.I. and was a solid at room temperature. The gas oils were prepared by distilling the gasoline cut, and then continuing distillation of the gas oil until coking occurred. The gas oils prepared in the manner described had gravities in the vicinity of 30° A.P.I. and provided a good feedstock for the hydrogenation plant. The temperatures used in the reactor during these runs were: 850°F, 875°F, 900°F, and 925°F. The space velocities varied from 1.9 to 4.0. It was found that the gasoline yields increased as the temperature increased and as the space velocities decreased. However, it was noted during these experimental runs, gas formation occurred at 925°F which increased as the space velocities decreased. Gasoline yields varied from around 36 percent with a space velocity of 4 at 850°F, to 64 percent with a space velocity of 1.9 and at 925°F. At the higher temperature, a loss of 12 percent in liquid products was sustained which resulted in the formation of hydrocarbon gases.

Further description of the hydrocracking runs is contained in a paper written by Senior student John Giesler. This paper will be presented by Mr. Giesler at a meeting of the Western Petroleum Refiners Association, to be held at Witchita, Kansas, the latter part of June, 1960.

A typical hydrocracking run with the Red Springs gas oil is described below:

Catalyst	Cobalt Molybdena
Preheater temperature	380°C
Reactor temperature	450°C
Hydrogen feed rate	16.69 scf/hr
LHSV	1.879
Volume of hydrogen pumped	116.83 scf
Volume of off gases	111.67 scf
Volume of oil pumped	11,319 ml
Volume of oil yield	11,808 ml
Total yield by volume	104.3%
Gasoline yield to 375°F	42.9%
Diesel fuel yield to 660°F	57.0%

COAL RESEARCH

Edward Prostel

Washing Hanna Coal: This project was carried over from the previous year. Ten samples of coal from Hanna, Wyoming were examined for their washability. A report was submitted to the sponsor December 3, 1959. The ash as well as the sulfur in the coal is distributed fairly evenly over the whole gravity range, separation by gravity, therefore, does not look promising.

Smokeless Briquets: Starting in September, considerable work was done on the preparation of smokeless briquets from low rank coals. Aggregate size was investigated to a minor extent. A large number of coals were tested, first carbonized on a laboratory basis, then briquetted. All briquets were submitted to a uniform ignition test. Likewise, a large variety of oxidizing agents was investigated to determine their effect on the ignition time of the briquets. There are a number of low rank coals which can be made to perform rather well. Chemical additives were not too successful, mainly as they usually contribute to the ash, the unpleasant odor, and to the cost of the briquets. Ignition time is improved by a comparative loose structure of the briquet which may be obtained by low briquetting pressure, smaller aggregate or by a spongy structure of the coal. A report on this work is expected to be submitted within the next month.

Miscellaneous: Water of decomposition in the process of carbonization was determined on a subbituminous coal for a sponsor.

International Briquetting Association: The biennial meeting of this Association in August, 1959 was attended. A paper was presented on the production of synthetic coke comprising of the results obtained up to that date.

The report of the Standards Committee of this Association was prepared and submitted. It contained the Drop Shatter Test which was adopted as standard at the biennial meeting and the new Compression Strength Tests which were amended at the same time.

The proceedings of the meeting were published near the end of the year, edited in cooperation with Neal Rice.

DETERMINING PROPERTIES OF CARBONS AS PRACTICED AT N.R.R.I.

Neal Rice

The properties which determine the value of activated carbons are surface area and its availability. The retentivity, and also the willingness of a carbon to release adsorbed molecules, also determine its potential service.

At N.R.R.I., several pieces of equipment have been built and are in use which makes possible the determination of these properties. We are able to find the internal surface accessible to methanol by means of an adiabatic calorimeter which measures heat release upon wetting. This is directly proportional to the area wetted. For instance, an activated carbon may release 26 cal/gram which indicates a surface area of 260 square meters exposed in the pores throughout the material. These pores are accessible to methanol down to 5A° in diameter. A coke, however, made at the same temperature by different procedures may have a heat of wetting of only .26 cal/gram and a surface area little greater than the outside areas of the individual particles, 2.6 square meters.

Apparatus for determining adsorbed gases gravimetrically is in use. This balance consisting of a quartz spiral supporting a 20 mg sample under proper evacuation indicates the take-up and release of hydrocarbon or other vapors in micrograms. This process is followed under varying pressures and at a series of temperatures, thus telling us what materials and how much a given carbon will adsorb and hold and under what conditions they will be released.

Another procedure tells us the reactivity of a carbon to CO_2 or to O_2, measuring CO_2 decomposed and CO produced through any range of temperatures. This property of a carbon indicates its usefulness as a reducing agent or as a fuel.

Apparatus has been newly designed and built in which a carbon may be degassed and dried and a displacing liquid admitted in the absence of air. This makes possible complete occupancy of the minute pores by displacing liquid without the presence of molecules of O_2, N_2 or other atmospheric gases.

The determination of specific gravity of fine powders of porous carbons is fraught with many stumbling blocks. Here we have devised pycnometers in which our carbons displace mercury to determine an apparent gravity and the porosity below mercury's penetration pore size, but above that of methanol. These procedures give us further knowledge of the properties of coal and its derivatives.

Helium density apparatus has been constructed and set up. Work with this procedure is anticipated for the summer and fall of this year.

ANALYTICAL LABORATORY

Carter H. Trimble

Purpose: The analytical laboratory is a service laboratory set up to perform chemical analyses upon materials submitted by personnel of the Research Institute or by individuals and organizations which are exploring or developing the natural resources of the State of Wyoming.

Work Performed During the Past Fiscal Year: The analytical work performed by this laboratory is tabulated below as to type of sample and type of determination required. Estimated work for June, 1960, has been included.

Table I represents, primarily, individually submitted ore and mineral samples from prospectors. Little change will be noted from the previous years report in this section. Table II lists samples received for complete analysis. In this section, a comparison with the previous years report will show a considerable increase in both the number of samples and the amount of work performed. Table III lists work done on Institute projects and represents the bulk of the laboratory work load for the year.

During the past year, a total of 1364 samples were received for analysis compared to 427 samples for the previous year. The actual work load of the laboratory is better represented by a total of 4563 analytical determinations for the past year compared to a total of 1674 determinations performed during the previous year.

Table I

Determinations of Individual Elements

Aluminum	12	Iron	18	Potassium	2
Ash	7	Lead	2	Silica	5
Calcium	12	Manganese	1	Silver	22
Cesium	1	Mercury	1	Sodium	3
Chlorine	2	Moisture	11	Sulfur	28
Cobalt	3	Molybdenum	1	Titanium	5
Copper	3	Nickel	4	Uranium-Chemical	6
Germanium	3	Nitrogen	18	Uranium-Fluorometric	6
Gold	22	Phosphorus	6		

Total Determinations -- 204

Representing 115 samples

Table II

Samples Received for Complete Analyses

Bentonite	13
Coal	259
Coal Ash	1
Glass Sand	1
Limestone	3
Phosphate Rock	3
Silicate Rock	8
Total Samples	288

Representing 2013 individual determinations

Table III

Project and Miscellaneous Samples

Coal Ash Project	293
Gros Ventre Placer Project	46
Ion Exchange Eluates	27
Phosphate Rock Project	487
Trona Core Project	64
Carbon Samples	38
Water Analysis	6
Total Samples	961

Representing 2346 individual determinations

Total Samples Received for the Year - 1364
Total Number of Determinations - 4563

553.7
W98
1961/62

59

# Eighteenth Annual Report

JULY 1961 to JULY 1962

Natural Resources Research Institute

COLLEGE OF ENGINEERING
UNIVERSITY OF WYOMING
LARAMIE, WYOMING

THE LIBRARY OF THE
NOV [illegible] 1962
UNIVERSITY OF ILLINOIS

The Natural Resources Research Institute, or NRRI, was established in 1943 and reorganized in 1949 as the Engineering Experiment Station of the University of Wyoming. During the 1961-62 year it has been reoriented toward being more nearly the Research Department of the College of Engineering.

The purpose of NRRI is to promote Wyoming's economic growth through research on ways of utilizing our natural resources. Much of this research is accomplished with the full time staff of NRRI in its laboratories. In addition many of the research projects are performed with the other facilities of the College of Engineering and part time work by the College's academic staff and graduate students as an integral part of its expanding program of graduate education.

Most of NRRI's research projects are performed in cooperation with other State, federal and private agencies. They are supported by State appropriations and contracts with other governmental agencies, corporations and individuals. In addition NRRI's laboratory facilities and staff are available, on an at cost fee basis, as a materials testing and assay service.

333.7
W9r
1961/62

EIGHTEENTH ANNUAL REPORT
# of the
NATURAL RESOURCES RESEARCH INSTITUTE
July 1961 to July 1962

BRIEF AND TABLE OF CONTENTS

Section — Page

1. GOALS: The goals of NRRI were clarified during this year as being: 1
   - 1st: To help educate graduate students;
   - 2nd: To increase knowledge with research results; and
   - 3rd: To provide services to sponsors of research.

2. RESEARCH PROGRAMS: In order to provide a broad base of graduate and staff research opportunities, broad programs of research have been established in the fields of: 3
   - a. Full Utilization of Coal 4
   - b. Water Resources, including Weather Modification 5
   - c. Mechanical Dynamics, and 6
   - d. "Informatic" Data 6

3. RESEARCH PROJECTS: Specific research projects have been conducted in the fields of: 9
   - a. Synthetic Coke for the Union Pacific Railroad Foundation 10
   - b. Coal Utilization for the Pacific Power & Light Company 10
   - c. Coal Tar and Black Oil Hydrogenation for the Wyoming Natural Resource Board 11
   - d. Test and Assay Services for various individuals and companies 12
   - e. A Bibliography of Wyoming Water Resource Data for the Wyoming Legislative Council 12
   - f. Weather Modification for the U.S. Bureau of Reclamation 12
   - g. Vibration Test Fixture Studies for the Martin Company 13
   - h. Informatic Data Master's Theses 14

4. PERSONNEL: The full time research staff of NRRI remained static at 6 people during the year; it was augmented by 8 of the academic staff during July and August of 1961; by 12 graduate research assistants during the school year; and by 13 of the academic staff and graduate students during June 1962. 15

5. PUBLICATIONS AND COMMITTEE ACTIVITIES: NRRI staff members have participated in the activities of several national technical organizations, and have published several papers in addition to their reports on contracted work. 17

1. GOALS

The Natural Resources Research Institute has been undergoing an expansion and modification of organization the last two years. This report is concerned largely with the purposes and results of that growth.

A clarification of the purposes of NRRI has been based largely upon extensive conversations during the summer of 1961 with the administrations and staffs of the twenty universities of the eight Rocky Mountain States. These conversations were chaired by Dr. Bellamy and were a major part of a survey conducted by the Associated Rocky Mountain Universities. Its purpose was to determine optimum kinds of relationships between the National Aeronautics and Space Administration and the members of the Associated Rocky Mountain Universities both individually and collectively.

It became clear during this survey that all universities have the following three general purposes.

1. To disseminate knowledge, or to educate;
2. To acquire knowledge, or to perform research; and
3. To utilize knowledge, or to provide services to the public.

Considerable variation was found in the relative emphasis placed upon these three purposes by various universities throughout the country. Some place equal importance on all three with a fairly common result that service or research activities tend to overshadow, especially, undergraduate education. In contrast, the University of Wyoming (in common with a majority of the Rocky Mountain Universities) definitely ranks the importance of these three purposes in the order listed.

This emphasis upon "education first" has hitherto been reflected as an emphasis upon (and as an excellence in) undergraduate education with which few research activities are directly related. It is, however, now becoming increasingly necessary and desirable to establish much stronger programs of graduate education in the University of Wyoming, as well as in many of the other Rocky Mountain Universities. It is thus also becoming necessary to greatly increase research activities within the University; graduate education can be characterized as being largely education in the research process itself. Still, the emphasis at the University of Wyoming is more upon research as a part of graduate education than upon finding particular research results, per se.

Consequently the goals of NRRI are, in order of their relative rank or emphasis:

1st. To help educate graduate students;
2nd. To increase knowledge with research results; and
3rd. To provide service to sponsors of research.

2. RESEARCH PROGRAMS

The organizational function of NRRI has thus been established as being primarily to provide graduate students and staff with opportunities for research. This can best be accomplished by establishing broad programs of research. Only in this way can it provide for the highly individual research interests of each of the research staff, the academic staff, and the graduate students of the College of Engineering. In addition, the programs should, insofar as possible, serve the research interests of those in as many other Colleges of the University as might be interested in interdisciplinary research problems.

Many criteria are used to select which research programs are to be established. For example, Wyoming's public and students are best served with research programs aimed at finding better ways of understanding and utilizing the State's natural resources; or of expanding the State's industry and standards of living. They must also be programs in which the research staff and students have deep personal interest; only then can notable research results be expected. In addition, they should be programs for which financial "project" support in the form of grants and contracts can be obtained; the high costs of research make graduate education much more expensive than undergraduate education.

It is possible to satisfy many such criteria simultaneously. For example, the staff and students at the University of Wyoming tend to be interested primarily in the development of Wyoming's resources and industry. Their individual interests are thus also frequently of direct interest and service to other State agencies or industries. Those agencies or industries can then well afford to help provide financial support for particular projects within the over-all research programs.

Or, in brief, NRRI's "education first" responsibility is served largely by establishing and sponsoring broad programs of research in conjunction with the educational program of the Graduate School. Such programs, by providing individual staff members and graduate students opportunities for work in their particular fields of interest, thus tend to insure maximum research returns of increased knowledge. In addition, greatest service can be rendered to sponsors of research projects if those projects are self-motivated, on-going research which is a part of (and which is made possible by) a vigorous research program in that general field.

Four such broad research programs have now been established, or are now being established. A brief description of each of them follows.

2a. Full Utilization of Coal

The general field of "material resources" or "resources from the land" has been, and still is, predominant in NRRI's activities. During the last year particular emphasis has been placed on one aspect of that general field; namely the "full utilization of coal". This emphasis reflects a recognition of the State's extensive coal reserves, the current low ebb of the coal mining industry, and the deep personal interest of most of NRRI's permament research staff in various aspects of this program.

Briefly, carbonizing raw coal separates it into gaseous, liquid and solid fractions, each of which have unique utility. For example, the gaseous products might well be used as the source of heat for the carbonization processes, leaving the liquid and solid fractions as beneficiated products. With proper processing, the liquid fractions might then become a source of liquid hydrocarbons with petroleum-like characteristics which might markedly extend our petroleum reserves. The solid or coal char fractions have a variety of potential uses such as metallurgical carbons, coke substitutes, smokeless fuel briquetts, activated carbons, cast or shaped refractories, etc.

Of course the primary utility of, especially, the solid or char fraction of coal is - and is likely to continue to be - for combustion to provide a source of heat energy. The recent development of shipping "coal by wire" (or of constructing steam powered electrical generating plants near coal mines) offers a very attractive solution to the problem of high costs of transporting large amounts of Wyoming coal. Prime examples of this development are the successful operation and current expansion of Pacific Power and Light Company's Glenrock plant, and the current construction of Utah Power and Light Company's Kemmerer plant. NRRI is currently investigating the possibilities of utilizing precarbonization of the fuel for such power plants in order to utilize more fully the unique properties of the liquid fractions of the raw coal.

2b. Water Resources

A research program in the field of water resources has been established in recognition of the primary importance of this resource to the State of Wyoming, and of the interests and capabilities of many of the staff and graduate students of the College of Engineering.

NRRI's approach to water resources is extremely broad. For example, since nearly all of Wyoming's water comes from the atmosphere, the airborne phase of the hydrological cycle is receiving considerable attention. This includes studying the possibilities of modifying weather to increase water supplies. It even involves studies of how best to utilize weather satellites since they provide an extremely promising source of hitherto unavailable information concerning storms as well as the basic radiational driving force of all weather phenomena. At the other extreme, ways of utilizing underground sources of water, and perhaps of purposefully recharging them with appropriate weather modification operations, will also receive their share of attention.

All of this is to be in addition to research into better ways of understanding, describing and utilizing the State's surface water resources.

2c. Mechanical Dynamics

An important phase of research into ways of utilizing natural resources involves the instruments and machines with which they might be observed and utilized. Consequently it is within the province of NRRI to establish programs of research in basic electrical and mechanical engineering fields upon which improved future instruments and machinery (and future manufacturing industry within the State) will ultimately depend. NRRI must obviously also sponsor such basic research if it is to provide research opportunities to the staff and students in the Departments of Electrical and Mechanical Engineering.

One of the first research programs of this kind to be established is in the field of "mechanical dynamics" in response to the interests of several of the staff of the Mechanical and Electrical Engineering Departments. The general goal of this program is to learn more about the causes and effects of dynamic responses of materials and equipments to such things as shocks and vibrations.

2d. "Informatic" Data

A basic problem in all kinds of natural resources activities is how better to acquire, process and utilize the ever growing amounts of quantitative data involved. A broad program of research into new, "informatic", ways of quantitatively processing large amounts of data has thus been established. The term "informatic" reflects the fact that now, for the first time in history, it is possible (at least in principle) to perform all quantitative aspects of data operations automatically. It also reflects the fact that there will still remain the qualitative interpretations of the data which can only be accomplished manually. Or, the goal of NRRI's "informatic data" research program is to find out how best to utilize machines to acquire and process quantitative data in order to portray to men whatever information they might contain.

This informatic data research program provides an exceptional breadth of interdisciplinary research opportunities. For example, the equipments with which the quantitative operations are to be performed fall within the province and interests of Electrical Engineering, Mechanical Engineering and Chemistry. Since informatic forms of data are, in effect, a new pictorial way of writing down numbers, the determination of optimum forms of notation involves Mathematics, Art, Psychology and Philosphy. On the other hand the kinds of "pictures" they are to present depend largely upon the particular kinds of things they are to portray. This research program is thus of direct importance and interest to such varied fields as Botany, Economics, Geography, Geology, Physics, Zoology, Physiology, Statistics, Agriculture (in general) as well as Agricultural, Civil, General and Petroleum Engineering.

The informatic data research program seems likely to grow into a basic program with which to identify NRRI's contributions in many of its other research programs. For example, greatest emphasis in the water resource program is being given to its critical problems of data acquisition, processing and utilization. Similarly, as the informatic data program progresses it can well serve to provide a means of contributing significantly to the solution of many other kinds of technical problems. Last, but hardly least, the informatic data research program might well establish the basis of a strong, broad, "home grown", instrumentation industry within Wyoming.

The informatic data research program has been well started during the last year. The general background for the overall program of "Informatic Research at the University of Wyoming" has been established in an NRRI Report entitled "1. Informatic Forms of Data, 1961". A second report of the Informatic Data Research series entitled "2. Geospheric Data

Systems" indicates its general applicability to problems of geology, hydrology, meteorology and space exploration and utilization.

3. RESEARCH PROJECTS

In general only State legislative appropriations are available for direct continued support of such broad research programs. However such direct support from State taxes can probably never be sufficient to defray the high costs of the minimum research program required to educate Wyoming's youth.

But neither should State taxes bear the entire expense of such research. Many of the research results will frequently turn out to be at least as beneficial to the country as a whole as to Wyoming in particular. Also they will often be of much greater use to some particular private industries or interests than to others. Or, it is both necessary and desirable that much of the expense of NRRI supported research also be defrayed by federal and private funds.

Experiences with federal and private funding of research at other universities indicates, however, that they can become excessive and quite incompatible with a policy of "education first". Consequently it is the policy of NRRI to build its research staff (of full time researchers plus divided time researchers and graduate teachers) no larger than that which is supported by direct legislative appropriations for broad research programs. Research activities are then to be expanded to the degree that this research staff attracts federal and private support for themselves and their assistants on projects within the general programs, and for which they have special interests and capabilities. Whatever project funds become available to support the research staff then frees an equal amount of legislative funds for establishing or supporting other research programs of general interest and value to the State as a whole.

To illustrate, the first seven of the following research projects have been funded by federal, private and other State agencies during the last year of operation. The "extra" funds obtained from such contracts are making it possible to provide the general support for graduate students indicated in Section 4, to support exploratory research in the informatic data program, and to help establish other broad research programs.

3a. Synthetic Coke for the Union Pacific Railroad Foundation

Much of this year's program for full utilization of coal has been sponsored by a second yearly grant of $25,000 from the Union Pacific Railroad Foundation for investigations of the possibilities of manufacturing synthetic coke from southern Wyoming coals. The chars obtained by carbonizing these coals have been quite successfully converted into synthetic cokes at the laboratory level of production. Six batches of such coke (made from three different coals with three methods of carbonization and with two kinds of binder, but all with quite uniform physical characteristics) were selected from many batches and tested for their electrical characteristics and metallurgical performance. Although minor differences were found between specimens, their electrical properties were found to be somewhat similar and they all have quite high reactivity in phosphate reduction tests.

This two year research project has thus ended with a positive conclusion; it has been possible to manufacture very satisfactory synthetic coke from southern Wyoming coals in the laboratory. We are now recommending that this work be extended to the development and testing of production techniques in a pilot plant scale of operation.

3b. Coal Utilization for the Pacific Power and Light Company

Grants of approximately $25,000 have been provided during the year by the Pacific Power and Light Company to investigate means of more fully utilizing the coal from the State's largest operating coal mine; namely its mine which supplies its Glenrock electrical generating plant. This work has been a mixture of theoretical and developmental research. It has been related primarily to the carbonization of the Glenrock coal, and has involved the determination of surface and other properties of the resultant chars. Emphasis has been placed upon means of utilizing the chars in their original carbonized state, and upon means of modifying the chars for certain special applications.

3c. Coal Tar and Black Oil Hydrogenation for the Wyoming Natural Resource Board.

A continuing research project which can conveniently be classified as being another phase of the program for full utilization of coal involves hydrogenation of coal tars and of heavy black oils. This kind of work has been sponsored for several years by grants from the Wyoming Natural Resource Board; its grant for the past year was $7,000.

Much of this year's effort has been expended upon relocation, construction and repair of equipment largely by student assistants. The installation of a continuous-flow hydrogenation plant in the new laboratories of the Petroleum Engineering Department was completed about December 1, 1961. One hydrogenation run of a heavy gas oil was completed with this plant before an explosion occurred on December 15, 1961 during an attempt to hydrogenate a shale oil. The remainder of the year has been spent largely in cleaning and repairing the explosion-damaged wiring of the hydrogenation plant, and in constructing a combination delayed coking, cracking and reforming plant. It is expected that both plants will be in full operation during July, 1962.

The successful hydrogenation run was made on a heavy gas oil derived from an Oregon Basin crude oil. The principle result of this investigation was a demonstration that the yield of aromatic and olefin compounds in the gasoline fraction of the hydrogenated product more than doubled with an increase of reaction temperature from 450° to 490°.

In addition some of the products of earlier hydrogenations of tars and oils have been further identified by fractional distillations during the year.

3d. Test and Assay Services

The test and assay service offered by NRRI on a time and material basis made some 4100 analyses and tests on samples from 58 different sources during the year. 47% of these analyses and tests were of samples which originated within the Institute as part of its research projects. The remaining tests were made for fees of about $3,000 on samples from various individuals and companies within the region. A few of the determinations were performed as a service to other departments of the University.

3e. A Bibliography of Wyoming Water Resource Data for the Wyoming Legislative Council

The first sponsored project in the water resource program was a contract for $7,000 with the Wyoming Legislative Council. The first task under this contract was to prepare "A Bibliography of Wyoming's Water Resource Data"; it was completed in June 1962. The second task is to illustrate how the new informatic forms of data might be utilized to help solve Wyoming's water resource problems, and the third is to recommend to the Legislative Council what steps should be taken to improve the acquisition and utilization of water resource data within the State. Reports on each of these three tasks are to be completed by September, 1962.

3f. Weather Modification for the U.S. Bureau of Reclamation

The second sponsored project under NRRI's water resource program is financed with a $30,000 contract with the U.S. Bureau of Reclamation. This amount is intended to fund the University of Wyoming's part of a two year initial or exploratory phase of a long range research program. It involves cooperative efforts with the Bureau of Reclamation, the U.S. Weather Bureau, the South Dakota

School of Mines and Technology and the University of Nevada. The general purpose of this program is to investigate, from an engineering point of view, the possibilities of increasing water supplies with weather modification operations. NRRI's responsibilities lie primarily in the field of establishing more appropriate data processing procedures for studying and controlling weather modification operations, and in the investigation of whatever weather modification procedures might be found to be particularly suitable for use in Wyoming.

It was determined at the outset of this project that a detailed study of "cap" or "scarf" clouds which occur in the winter over the higher mountain peaks in Wyoming might well result in greatly increased knowledge of how to usefully induce artificial precipitation. The first step in such a study is to obtain a detailed census of the occurrence of cap clouds (and other clouds) over the mountains throughout the year. This cloud census is now being acquired with time-lapse photographs (at 2-minute intervals) of the clouds over the Snowy Range west of Laramie. It is planned to continue and extend such time-lapse photography throughout the year, and to initiate several other lines of research during the summer of 1962.

3g. Vibration Test Fixture Studies for the Martin-Marietta Corporation

The first sponsored project under the program in mechanical dynamics was an $8,000 contract with the Martin-Marietta Corporation of Denver, Colorado. It was initiated in December 1960 and completed in December 1961.

This project was a preliminary analytical study of the dynamic behavior characteristics of oil bearing vibration tables. Its purpose was to establish plans for a subsequent, more complete and detailed, experimental and analytical investigation of this subject. It is expected that continuing work in accordance with these plans will be financed sometime next year, and that this work will add to fundamental knowledge on how to conduct more reliable and meaningful vibration tests on missile components and similar equipments.

3h. Informatic Data Master's Theses

Many individual projects on various aspects of the informatic data research problem have been pursued during the year. Most of these individual projects have been pursued by graduate students and are to result in theses for advanced degrees. The following three Master's theses of this type were completed during the summer of 1961.

"An Investigation of the Use of a Magnetostrictive Delay Line as a Three State Memory Device" by Garth H. Foster.

"Analog to Unitary Data Converter Using Photoelectric Techniques" by Virgil G. Ellerbruch.

"Mapping: The Universal View" by Robert L. Champlin.

4. PERSONNEL

Since NRRI's organizational function is largely to provide graduate staff and students with research opportunities, its accomplishments can also be measured by the following list of personnel involved in and supported by its research programs.

EXECUTIVE COMMITTEE:
H. T. Person, Dean of Engineering, Chairman
G. D. Humphrey, President, Ex Officio
H. D. Thomas, State Geologist
R. A. Morgan, Assistant Dean of Engineering
A. J. McGaw, Head of Civil Engineering
J. C. Bellamy, Director of NRRI, Secretary

RESEARCH STAFF:

John C. Bellamy, Director
Walter E. Duncan, Assistant Director
Ralph D. Law, Petroleum Chemist
Edward Prostel, Coal Research Engineer
Neal Rice, Coal Research Chemist
Dan B. Field, Analytical Chemist

SUPPORT STAFF:

Oren F. Neal, Mechanic
Carson O'Dell, Technician
Nancy K. Stumpf, Secretary (Resigned)
Thelma G. Hensen, Secretary
Kathryn Anderson, Typist (Resigned)
Coralie Sue Gay, Typist (Resigned)
Karen L. Sturdevant, Typist

DIVIDED TIME (RESEARCH AND TEACHING) STAFF

	Summer 1961	1961-62 School Year	Summer 1962
Robert L. Sutherland.....Mechanical Engineer	X	X	
J. Earl Foster..........Mechanical Engineer		X	
Robert Wheasler.........Mechanical Engineer		X	
Kenneth R. Beach........Electrical Engineer	X	X	
Donald L. Veal..........Civil Engineer	X		X
Samuel D. Hakes.........Electrical Engineer	X		X
Charles N. Rhodine......Electrical Engineer	X		X
Phillip M. Hoyt.........Civil Engineer	X		X
Frank J. Trelease, III...Hydrologist	X		
Richard E. Mabie........Graphics Engineer	X		
Leonard B. Baldwin, Jr...Civil Engineer			X
Robert L. Champlin......Civil Engineer			X
Anton C. Munari.........Hydrologist			X
Merlin C. Williams......Hydrologist			X
Chesley W. Angle........Mechanical Engineer			X
GRADUATE RESEARCH ASSISTANTS			
Robert C. Baldridge.....Civil Engineering		X	
John Tamvakis...........Civil Engineering		X	
Merlin C. Williams......Civil Engineering		X	
Rayburn Chadwick........Electrical Engineering		X	
James Fenton............Electrical Engineering		X	
Dewey Henderson.........Electrical Engineering		X	
Larry Hulbert...........Electrical Engineering		X	
James Price.............Electrical Engineering		X	
Michael K. Rodda........Electrical Engineering		X	X
Gary Guilford...........Mechanical Engineering		X	
Richard D. Hanly........Mechanical Engineering		X	X
Max T. Kershisnik.......Mechanical Engineering			X
Francis P. Miknis.......Physics		X	X

STUDENT LABORATORY ASSISTANTS

Robert H. Abel
Jack G. Adams
Uwe H. Dahl
Victor Duran
Raymond L. Forebuck
Dennis M. Kiser
Robert W. Larson
Theodore L. Loudon
Edwin L. Lowe
George Miyake
James T. Moncur
Robert L. Moncur
William J. Preece
Keith B. Purinton
Gandi Rajender
Kenneth D. Somers
Clinton D. Stoddard
James W. Stugart
Martin R. Tadlock
Marion E. VanZee
Edmund V. Waite

5. PUBLICATIONS AND COMMITTEE ACTIVITIES

This year's work of the research staff of NRRI has included the following notable technical activities.

John C. Bellamy:
- American Meteorological Society -
  - Member of Long Range Planning Commission,
  - Member of Committee on Atmospheric Measurements.
- Institute of Navigation -
  - Western Regional Vice President
  - Member of the Council.
- Associated Rocky Mountain Universities, Inc.
  - Chairman of the Summer (1961) Study Team for the National Aeronautics and Space Administration.
- National Academy of Science, Space Science Board -
  - Participant in the Space Science Summer (1962) Study.

Walter E. Duncan:
- American Institute of Mining, Metallurgical and Petroleum Engineers -
  - Chairman, Wyoming Mining and Metals Section.

Neal Rice
- International Briquetting Association -
  - Secretary-Treasurer,
  - Chairman of the 7th Biennial Conference, August 1961
- American Society for Testing Materials -
  - Member, Committee D-5 on Coal and Coke with assignments to:
    - Sub-committee 18 on Classification of Coals and
    - Sub-committee 25 on Physical Testing of Briquetts.

The following papers (in addition to contractual reports) have been published during the year by NRRI's full time research staff.

"Properties of Chars Produced from Low Rank Coals of the Rocky Mountain Region" by Katsuya Inouye, Neal Rice and Edward Prostel in Fuel, 41, January 1962, pp. 81-91 (NRRI Reprint No. 21).

"Informatic Forms of Data", by John C. Bellamy for the Society of Automotive Engineers' Automotive Engineering Congress, Detroit, January 1962. (NRRI Informatic Data Research Series No. 1).

"Instrumentation for Aeropilotage" by John C. Bellamy in Draper Anniversary Volume, McGraw-Hill, Inc., New York, New York, 1962.

"Geospheric Data Systems" by John C. Bellamy, NRRI Informatic Data Research Series No. 2, November 1961.

W98
1960/61

Seventeenth Annual Report

JULY 1960 to JULY 1961

Natural Resources Research Institute

COLLEGE OF ENGINEERING
UNIVERSITY OF WYOMING
LARAMIE, WYOMING

LIBRARY OF THE
NOV 1962
UNIVERSITY OF ILLINOIS

The Natural Resources Research Institute, or NRRI, was established in 1943 and reorganized in 1949 as the Engineering Experiment Station of the University of Wyoming. During the 1960-61 year it has been reoriented toward being more nearly the Research Department of the College of Engineering.

The purpose of NRRI is to promote Wyoming's economic growth through research on ways of utilizing our natural resources. Much of this research is accomplished with the full time staff of NRRI in its laboratories. In addition many of the research projects are performed with the other facilities of the College of Engineering and part time work by the College's academic staff and graduate students as an integral part of its expanding program of graduate education.

Most of NRRI's research projects are performed in cooperation with other State, federal and private agencies. They are supported by State appropriations and contracts with other governmental agencies, corporations and individuals. In addition NRRI's laboratory facilities and staff are available, on an at cost fee basis, as a materials testing and assay service.

333.7
W99
1960/61

SUMMARY OF NRRI MATERIALS INVESTIGATIONS

July 1960 to July 1961

NRRI's staff research activity during the year has been concerned primarily with sponsored projects directed at utilization of coal and coal products. This work included:

Production of synthetic metallurgical coke from non-coking western coals.

Utilization of chars as a source of activated carbon and as a material for a manufactured barbecue briquet.

Evaluation of coal fly ash as a pozzolan and as a metallurgical raw material.

Hydrogenation of low temperature coal tars to produce a material approximating petroleum crudes.

The rest of its activity was spread over a variety of research and testing. The research activities involved:

The development of equipments and procedures for measuring the density of carbons in helium.

Relationships between coal moisture and ASTM Hardgrove Grindability.

Relationships between molten coal ash viscosity and its chemical composition.

Viscosity of bentonite slurries.

The testing, exclusive of that done as part of the analytical and testing service, included many bentonite evaluations, magnetic concentrations of iron ores, evaluations of building stone, calcination of limestone, and evaluations of light weight aggregates.

The analytical and testing group served the staff and residents of the state by handling samples for identification and analysis. During the year this group performed some 1600 analyses related to the research activities of the staff and, in addition, handled 2300 analyses on samples submitted by residents of Wyoming and others. Some research has been done to find rapid methods applicable to certain hard-to-determine elements. Information is also being developed on an improved method of determining nitrogen in coals, chars and cokes.

PERSONNEL

EXECUTIVE COMMITTEE:

H. T. Person, Chairman
G. D. Humphrey, Ex Officio
H. D. Thomas, State Geologist
A. J. McGaw
J. C. Bellamy, Secretary

STAFF:

John C. Bellamy	Director
Walter E. Duncan	Assistant Director
Ralph D. Law	Petroleum Chemist
Edward Prostel	Coal Research Engineer
Neal Rice	Coal Research Chemist
Dan B. Field	Analytical Chemist
Carter H. Trimble	Analytical Chemist
Oren F. Neal	Mechanic
Carson O'Dell	Technician
Nancy K. Stumpf	Secretary
Kathryn Anderson	Part Time Typist

PART TIME RESEARCH FACULTY:

Robert L. Sutherland	Mechanical Engineer
Kenneth R. Beach	Electrical Engineer
Donald L. Veal	Air Transport Engineer
Samuel D. Hakes	Electrical Engineer
Charles N. Rhodine	Electrical Engineer
Phillip M. Hoyt	Hydrologist
Frank J. Trelease, III	Hydrologist
Richard E. Mabie	Graphics Engineer

LABORATORY ASSISTANTS:

R. Owen Asplund
Lloyd H. Baker
Bruce S. Beckley
Ralph J. Bille
Douglas C. Black
Delford G. Britton
Keith S. Campman
Donald Cetrone
Uwe H. Dahl
Kenneth A. Endsley
Frank O. Johnson
Lin Nar Loh
Lawrence K. Millay
William J. Millay
George Miyake
James T. Moncur
Robert L. Moncur
Frank E. Nichols
Keith B. Purinton
Gandi R. Rajender
Noel R. Rasmussen
Graham D. Sims
James W. Stugart
Martin R. Tadlock, Jr.
Richard P. Timmermeyer
A. Eric Taylor
Edmund V. Waite
Edward M. Young

Seventeenth Annual Report (1960 - 61)

NATURAL RESOURCES RESEARCH INSTITUTE

TABLE OF CONTENTS

Section Page

Summary of NRRI Materials Investigations i

Personnel ii

Table of Contents iii

1. Introduction 1

2. Land (Materials) Resources Research

2.0 Summary 2

2.1 Synthetic Coke Project 3

2.2 Coal Processing....................Edward Prostel 4

2.3 Surface Properties of Carbons.......Neal Rice 5

2.4 Petroleum Research.................Ralph D. Law 6

2.5 Non Metallic Research..............Walter E. Duncan 6

2.6 Test and Assay Services............Dan B. Field 7

3. Water Resources Research 8

4. Air Resources Research

4.0 Research Aircraft 8

4.1 Data Processing Techniques 9

5. Space Resources Research

5.1 Vibration Test Fixture Study 10

5.2 High Altitude Meteorological Requirements, 1965-75 10

5.3 Perspective Projections 10

6. Conclusions 10

Seventeenth Annual Report (1960-61)

NATURAL RESOURCES RESEARCH INSTITUTE
College of Engineering
University of Wyoming

1. INTRODUCTION

The purpose of the Natural Resources Research Institute is to promote Wyoming's economic growth through research on ways of utilizing our natural resources. Prior to the 1960-61 fiscal year its work had been almost entirely concerned with ways of utilizing minerals and fuels, or what might be called "land" resources. During this year, an expansion of scope of activities has been initiated to include other kinds of natural resources. For example, research into Wyoming's water resources was started near the end of the year. In addition, plans are well advanced for working on ways of utilizing our natural resources of the air and even of space for the benefit of the State's economy and general welfare.

This expansion of scope was initiated by a change of Director in September 1960 to Dr. John C. Bellamy whose background of experience has been in the fields of oil production, hydrology, meteorology, air navigation and space exploration. The research into ways of utilizing water, air and space resources are being conducted largely with the facilities of, and in conjunction with, the academic programs of the Agricultural, Civil, Electrical, Mechanical and General Engineering Departments. Continued expansion of land (or material) resource activity has been assured by placing it under the direction of Mr. Walter E. Duncan who has been advanced to the position of Assistant Director. In addition a very close working relationship is being established between NRRI and the new department of Petroleum Engineering.

NRRI's seventeenth year has thus seen a reorientation toward a much closer integration with the research activities characteristic of graduate education. Some of the basic concepts involved in that reorientation have been formulated in a paper, "Kinds of Natural Resources Research" by John C. Bellamy printed in December 1960. In accordance with its concepts, the four basic (land, water, air and space) kinds of natural resources are recognized and are being used to organize NRRI's more varied kinds of activities. Specific activities in each of these four fields are described below.

2. LAND (MATERIALS) RESOURCES RESEARCH

2.0 Summary

During the 1960-61 year covered by this report, work on materials resources was conducted under the sponsorship or for the account of the following organizations:

Benton Clay Company
Pacific Power and Light Company
J. R. Simplot Company
Black Hills Power and Light Company
Bureau of Land Management
Wyoming Natural Resource Board
Western Nuclear, Incorporated
Union Pacific Railroad Foundation

The study of the processing of low-temperature coal tars and Wyoming black oils has continued to receive substantial support from the Wyoming Natural Resource Board. In addition, short term testing and analytical projects were undertaken for private individuals.

During this year an integrated program of cooperative testing of concretes prepared from pozzolans and special aggregates, originating both within NRRI and elsewhere, was formalized with the Civil Engineering Department.

The equipment in the petroleum research laboratory at the Institute was dismantled during the summer of 1960 and reinstalled in the research laboratories of the Petroleum Engineering Department. Work on petroleum and coal tars under Institute direction and support is going forward in the new facilities. A new, combination delayed coking and catalytic cracking unit has been constructed and is being installed in the new laboratories. This unit will be used to prepare a stabilized feed for the hydrogenation units in which operating difficulties have been experienced due to the deposition of solid materials during the course of experiments. The new Petroleum Engineering Department is expected to serve as a catalyst for research activities of the Institute; the formal petroleum program will furnish practically trained laboratory assistants and eventually graduate students who will carry out more research in this general area.

2.1 Synthetic Coke Project

Work on Synthetic Cokes under a grant from the Union Pacific Railroad Foundation starting in January of 1960 and continuing through February of 1961, deserves special mention. A second grant extending this work was announced in May and active work on the project was resumed on June 1, 1961.

This work is directed at the production of a metallurgically acceptable reducing carbon with primary emphasis upon satisfying the requirements of the phosphorus industry. The work has gone forward along three separate but coordinated lines of study as follows:

1. Production of Synthetic Coke.
2. Determination of Physical and Chemical Properties, and
3. Metallurgical Testing.

It has been shown that strong synthetic cokes can be produced by briquetting low-volatile chars derived from Wyoming non-coking coals with the use of pitch and asphaltic binders. A number of factors have been found to markedly influence the strength of the resulting coke and a detailed study of these influences is underway to furnish information on processing which will maintain optimum quality of product.

In the study of the physical and chemical properties of the carbons, a parallel study has been made of the synthetic cokes and the chars from which these are derived. In addition, a number of standard metallurgical cokes have been studied. The density, porosity, surface area, resistivity at room temperature and reactivity of the carbon to carbon dioxide at 950°C of the chars and many of the synthetic cokes were measured. These tests confirmed earlier work showing that the porosity and surface areas of the chars and cokes made from western subbituminous coals are much higher than those from fusible coals. The resistivity of the cokes and their reactivity to carbon dioxide approximates that of the parent chars and is considerably higher than that of standard metallurgical cokes. In general this work has shown that, although the proximate and ultimate analyses of synthetic and standard cokes are very similar, their other properties are quite different. In addition it was shown that the operations of forming, curing and recarbonization have not materially altered these other properties; they are nearly the same for the synthetic cokes and their parent chars.

The metallurgical testing has been confined to a study of the reaction between the phosphate nodules and chars, synthetic cokes and standard cokes at several temperatures. The data obtained indicates that the parent coal does not have a controlling effect on the reactivity. The method used to prepare the primary char and subsequent processing steps do appear, however, to have a controlling influence on the resulting coke reactivity. Some of the synthetic cokes produced have reactivities as good as, or even superior to, that of standard metallurgical coke.

2.2 Coal Processing.................Edward Prostel

Smokeless Briquets

In addition to the work on the Synthetic Coke Project, reported elsewhere, the following activities are deserving of mention. An extensive investigation on the suitability of several low rank coals for the production of smokeless briquets which was started during the previous fiscal year was completed. A number of additives were examined to determine their suitability as oxidizing agents. A number of coals were found to be especially well suited on account of their physical structure. A final report was submitted to the sponsor in September.

Washability of Carbon Residue

A residue from an extraction process was examined in order to determine to what extent its ash content can be reduced by washing. The sample was separated in solutions of carbon tetrachloride and benzene of decreasing specific gravities, and the ash content of the fractions was determined. The results were reported to the sponsor in September.

Upgrading of Carbon Residue by Further Processing

A number of carbon residues were examined during the year and processed experimentally into smokeless briquets and synthetic coke. This work directed toward the production of synthetic coke was abandoned when it appeared that the physical structure of these raw materials ruled out the possibility of a product of high quality. However, good smokeless briquets were produced by adjusting production methods to the characteristics of the raw material. A final report was submitted to the sponsor in June.

Viscosity of Ash from Low Rank Coals

Difficulties with excessive ash viscosities have been encountered in a new boiler installation which utilizes Wyoming Coal. An intensive literature survey concerning this problem revealed that reported ash viscosity work here and abroad is based largely on higher rank coals. Practical laboratory work applicable to local coals has thus been started to learn more about the ash viscosity problem.

2.3 Surface Properties of Carbons...............Neal Rice

The surface properties of carbons prepared from Wyoming Coals have been under study during the 1960-61 year. A recent grant by the Wyoming Natural Resource Board will permit the acquisition of some special equipment for use in this area. Equipment has been conceived and built by means of which the surface area of carbons is estimated. Pore diameters are estimated by means of Iodine Number, Methylene Blue Number, and Molasses Number. Density determinations by displacement of mercury and of methanol are employed together with studies of carbon-carbon dioxide reactivity and electrical resistivity of a variety of carbons and cokes for several sponsors and in the connection with the Synthetic Coke Project.

Certain carbon residues are under study for a sponsor as a possible source for activated carbon. Activated carbon has been produced from these residues and further work is planned to improve the quality of the activated product. It is believed that gas adsorption carbons and catalytic carbons may be developed from the residues under study. Equipment for preparing these carbons is under construction or on order.

Special equipment to determine adsorption isotherms for various gaseous materials on carbon was constructed but has been employed with indifferent success. The same piece of equipment is also designed for estimating density and porosity by helium displacement. Preliminary testing is underway.

The group has determined hydrogen-carbon ratios in several coal products, and it has furnished glass blowing services for the laboratories.

A program for the Seventh Biennial Briquetting Conference, August 28-30 at Jackson Lake Lodge, was planned and papers solicited.

2.4 Petroleum Research............R. D. Law

The study of hydrogenation of tars and black oils has continued during the year. It has been assisted materially by a grant from the Wyoming Natural Resource Board which is to be continued into the coming year.

During the year, the equipment which had been installed in the NRRI building was dismantled and installed in new and enlarged laboratories in the new wing of the Engineering building where the new Petroleum Engineering Department is located.

Work with the hydrogenation equipment has pointed out the need for preparation of a stable, liquid, feed material because many interruptions had been encountered due to the precipitation of solid materials, asphaltenes and bitumens, in heated feed lines and valves. Small scale batch tests demonstrated that oil distilled to incipient coking proves to be superior feed material in the hydrogenation unit. Accordingly a small delayed coking plant has been designed and is now largely installed in the new laboratories. This unit has been constructed so that, by replacing the coking vessel with a catalyst chamber, the plant becomes a pilot catalytic cracking plant.

Some preliminary runs have studied cracking under hydrogen pressure to minimize deposition of carbon on the catalyst and thus increase its service life. These runs have yielded some interesting results in that the character and yield of gasoline is greatly affected by reactor temperature and flow rate. Particularly at higher temperatures, the output of non-condensable hydrocarbons goes up. Additional work with a high activity cracking catalyst is planned.

2.5 Non Metallic Research...........Walter E. Duncan

Bentonite Studies

There has been little opportunity during this year to actively pursue the long-range bentonite program. Near the end of the year a full-time laboratory assistant was engaged with the plan that approximately half of his time will be devoted to advancing the bentonite program after a period of training and orientation in the analytical laboratory. This work will be accelerated considerably next year by a recent grant of funds for this purpose from the Wyoming Natural Resoure Board.

One short study of the effect of aging on the viscosity of bentonite slurries was undertaken. Although the amount of work done does not justify conclusions at this time its results should be useful in a larger program of study planned for the future. Testing of prospecting and production bentonite samples has continued at a fairly high level.

Miscellaneous Activities

In addition to conducting the metallurgical testing portion of the synthetic coke project, reported elsewhere, the following activities are deserving of mention.

Some gabbos and placer samples were tested as sources of magnetic iron concentrates.

The defluorinated phosphate study referred to in last year's report was completed with the compilation of an annotated bibliography for the sponsor.

A study of several clays for evaluation as raw materials in the production of building brick was conducted under the sponsorship of Wyoming Natural Resource Board.

The study of utilization of coal ash has continued at a decreased level.

A short study on the calcination of a limestone for the production of metallurgical lime resulted in a product that was shown to be satisfactory by laboratory testing in the sponsor's plant.

The coordination of a number of different tests utilizing pozzolans and aggregates as concrete raw materials was effected.

A project involving liquid pyrolysis of wood is just getting under way.

2.6 Test and Assay Services..........Dan B. Field

During the period from June 1, 1960 to June 1, 1961, three thousand nine hundred twenty-five (3,925) analyses were completed and reported. These may be summarized as follows:

Type	Number	Percent
Commercial Operations	2231	56.84
Campus Department Analyses	53	1.35
NRRI Projects	1641	41.81
	3925	100.00

The past year gave an opportunity to serve the Geology Department, Anthropology Department, Soils Department and Wool Department.

Several investigations have been made in order to verify certain analytical procedures.

New absorptiometric methods are now available for fluorine, thorium, boron, germanium and tellurium. The laboratory has had no opportunity to check these methods for accuracy or reproducibility.

Work is continuing with the nitron method for nitrogen determinations. The data continues to grow with excellent reproducibility and duplication. Work will continue on this method until such time as the method is considered satisfactory for general use.

3. WATER RESOURCES RESEARCH

NRRI's first water resource research project is to prepare an "Index of Wyoming's Water Resource Data" under contract with the Wyoming Legislative Council. It was started on June 1, 1961 with Mr. Philip M. Hoyt of the Civil Engineering Department as project engineer and with the summer-time assistance of Mr. Frank Trelease III; it will be continued with graduate student assistance during the next school year and summer. Its purpose is to list the sources of Wyoming's water resources data and to highlight their inadequacies. It is also to illustratively evaluate the usefulness of some new kinds of data notations with which to automatically process and portray water resource information.

4. AIR RESOURCES RESEARCH

4.0 Research Aircraft

The U. S. Air Force transferred a surplus C-45H aircraft to the College of Engineering early in 1961; the modifications required to

obtain FAA certification and that certification has now been accomplished. It is currently outfitted with 5 passenger seats (in addition to the pilot's and copilot's seats) which can readily be removed and replaced with experimental equipment for a variety of research projects. Planned projects include (1) the development of "aeropilotage" techniques in conjunction with the newly introduced Air Transport Engineering program in the Civil Engineering Department, (2) the development and demonstration of improved aerial surveying techniques and (3) measurements of atmospheric conditions in conjunction with weather modification experiments. Mr. Donald L. Veal is currently engaged in flight-test development of aeropilotage techniques.

4.1 Data Processing Techniques

Several self-supported projects have been initiated towards the goal of developing improved forms of data with which to automatically acquire, process and portray meteorological data in more fully useful form. Four Master Degree research projects in Electrical Engineering are currently being pursued in this field under the direction of Mr. Kenneth R. Beach and Samuel D. Hakes. Beginning on June 1, 1961 Mr. Hakes and Mr. Charles N. Rhodine initiated the development of specific data recording equipments applicable to the fore-mentioned water resources research project and to aircraft instrumentation for use in aeropilotage procedures. In conjunction with such electronic research projects, a facility for producing printed-circuits is being established by Mr. Richard E. Mabie.

5. SPACE RESOURCES RESEARCH

From a natural resources points of view, "space" offers (among other things) the "resource" of perpetual motion of observational and communication satellites. For example, the use of weather observing satellites undoubtedly will, sometime in the future, provide much of the knowledge and data required for effective weather modification operations.

5.1 Vibration Test Fixture Study

Toward such ultimate objectives, Mr. Robert L. Sutherland of the Mechanical Engineering Department and Mr. Kenneth R. Beach of the Electrical Engineering Department are conducting a "Vibration Test Fixture Study" under a NRRI contract with the Martin Company, Denver.

5.2 High Altitude Meteorological Requirements, 1965-75

Dr. John C. Bellamy presented a paper with this title in Fort Worth on June 19, 1961 to a Super Sonic Transport critique sponsored jointly by the Institute of Navigation and the United States Air Force. The purpose of this paper was to establish those developments with which we can most quickly and economically avail ourselves of the full advantages of meteorological and communication satellites.

5.3 Perspective Projections

Developments of map making techniques are required if we are to fully utilize the weather data soon to be routinely available from satellites. Mr. Robert L. Champlin of the Civil Engineering Department is now completing a Master's Degree thesis on a newly developed kind of world map projection for this purpose. Plans are nearly complete for a NRRI project to apply these results to improved portrayals of Wyoming's airborne water resources as well as to weather satellite data.

6. CONCLUSIONS

In summary, NRRI's seventeenth year has been characterized by an expansion of the scope of its activities. Admittedly preliminary results of this expansion indicate that the close association with the College of Engineering's graduate education program will both (1) provide for increased and improved opportunities for graduate engineering studies in the University and (2) produce many more useful research results on ways of utilizing our natural resources. The expansion to research on water, air and space resources is being accompanied, in addition, by a continued expansion of NRRI"s research activities on ways of more fully utilizing Wyoming's land (or material) resources.

333.7
W98
1962/63

Nineteenth Annual Report

JULY 1962 to JULY 1963

Natural Resources Research Institute

COLLEGE OF ENGINEERING
UNIVERSITY OF WYOMING
LARAMIE, WYOMING

The Natural Resources Research Institute, or NRRI, was established in 1943 and reorganized in 1949 as the Engineering Experiment Station of the University of Wyoming. Since 1961 it has been reoriented toward being more nearly the Research Department of the College of Engineering.

The purpose of NRRI is to promote Wyoming's economic growth through research on ways of utilizing our natural resources. Much of this research is accomplished with the full time staff of NRRI in its laboratories. In addition many of the research projects are performed with the other facilities of the College of Engineering and part time work by the College's academic staff and graduate students as an integral part of its expanding program of graduate education.

Most of NRRI's research projects are performed in cooperation with other State, federal and private agencies. They are supported by State appropriations and contracts with other governmental agencies, corporations and individuals. In addition NRRI's laboratory facilities and staff are available, on an at cost fee basis, as a materials testing and assay service.

NINETEENTH ANNUAL REPORT
of the
NATURAL RESOURCES RESEARCH INSTITUTE
July 1962 to July 1963

BRIEF AND TABLE OF CONTENTS

Section — Page

1. GOALS: To achieve its goals; or — 1
   1st: To help educate graduate students;
   2nd: To increase knowledge with research results; and
   3rd: To provide services to sponsors of research;
   NRRI's activities were organized during the year in terms of various kinds of Operational Engineering which emphasizes the end-use motivations of science and engineering.

2. MINERAL OPERATIONS: Better ways of utilizing mineral resources from the land are being investigated with projects on: — 3
   a. Synthetic Coke for the Union Pacific Railroad Foundation; — 3
   b. Coal Utilization for the Pacific Power and Light Company; — 3
   c. Coal Tar and Black Oil Hydrogenation for the Wyoming Natural Resource Board; — 4
   d. Miscellaneous Mineral Projects; and — 5
   e. Test and Assay Services for various individuals and companies. — 6

3. WATER OPERATIONS: Better ways of surveying and utilizing water resources have been investigated with projects on: — 7
   a. Wyoming's Water Resource Data for the Wyoming Legislative Council; — 7
   b. Weather Modification Research with the U. S. Bureau of Reclamation; and — 8
   c. Establishing the Elk Mountain Water Resource Observatory. — 9

4. AIR OPERATIONS: Air resources were utilized and studied with: — 10
   a. Support of Weather Modification Experiments; — 10
   b. Reports on Aeropilotage; and — 10
   c. Proposed Aerodetic Units of Length. — 10

5. SPACE OPERATIONS: Research on ways of surveying and utilizing the resources of space included: — 12
   a. Participation in the National Academy of Science's 1962 Space Science Summer Study; — 12
   b. Participating in the Wyoming Space Age Industrial Workshop; and — 13
   c. Establishing Wyoming's Orbital Airline Program. — 13

6. OPERATIONAL INSTRUMENTATION: Research on better instrumentation for surveying and utilizing natural resources includes programs in: — 15
   a. Informatic Data Research; — 15
   b. Instrumentation Research for the Ideal-Aerosmith Company; — 17
   c. Sensing Devices for Road and Medical Operations. — 17

7. PERSONNEL: The full time professional research staff of NRRI increased from 6 to 8 during the year; was augmented by 13 of the academic staff and graduate assistants during July and August of 1962, by 11 graduate research assistants during the school year, and by 8 of the academic staff and graduate assistants during June 1963; and part time employment was provided for 16 student laboratory assistants during the year. — 19

8. TECHNICAL ACTIVITIES AND PUBLICATIONS: NRRI staff members have actively participated in several technical organizations as indicated by a summary of their publications during the year. — 21

1. GOALS

As discussed in the previous (18th) Annual Report, the Natural Resources Research Institute has been undergoing an expansion and modification of organization the last three years. This modification has been in the direction of establishing NRRI as being, in effect, the Research Department of the College of Engineering. The goals of this organization, in order of their relative rank or emphasis, are:

1st: To help educate graduate students;
2nd: To increase knowledge with research results; and
3rd: To provide service to sponsors of research.

Intensive study of ways of achieving these goals have resulted in the organization of NRRI with respect to various kinds of Operational Engineering activities. As indicated in the following discussions, programs in Mineral, Water, Air and Space Operations are now well established, and programs in Road and Medical Operations are now being established by staff members of the Civil and Electrical Engineering Departments. In addition, two closely associated graduate courses, CE 870D "Operational Engineering Analysis" and CE 871D "Topics in Operations Engineering," are being offered for the first time next year in the Civil Engineering Department.

The reasons for emphasizing the operational or end-use aspects of engineering education and research are discussed in detail in an NRRI publication of August 1962: "Operational Engineering at the University of Wyoming." Briefly it points out that a critical national need currently exists to strengthen engineering education in the end-use or operational aspects of engineering at least as much as in its engineering design and engineering science aspects. It is expected that this need will be served by NRRI's Operational Engineering program which is meant to provide:

- An educationally oriented mechanism whereby directly useful results from operational engineering research and service can be expected by industrial, state and federal agencies in return for their support,

- A general strengthening of engineering and related education throughout the University from greatly increased opportunities for operationally motivated yet largely intradisciplinary research; and
- An important specific capability for education in the operational-use aspects of engineering.

2. MINERAL OPERATIONS

The general field of Mineral Operations, or better ways of utilizing Wyoming's material resources in or of the land, has been and still is predominant in NRRI's research activities. During the last two years particular emphasis has been given to the "full utilization of coal" as indicated by the first three of the following discussions of specific mineral-operation research projects.

2a. Synthetic Coke

The Union Pacific Railroad Foundation has sponsored work directed at production of a metallurgically-acceptable synthetic coke from Wyoming's non-coking bituminous and subbituminous coals for more than two years. This was continued during the year with work on the second project in this series being completed and the Final Report released during July of 1962. The project was reactivated in January of 1963, with the start of a third, $26,000 project.

Briefly the work under the second project has shown that satisfactory cokes can be produced from a wide range of coal-ranks, utilizing all of the more common carbonization processes as the means of primary char production and binders derived from low temperature coal tars as well as asphalt. Physical and electrical testing of the cokes has shown that uniform properties can be achieved with all raw materials by suitable modification of processing steps. Metallurgical testing reveals however that there are differences in reactivity. The third project has for its objectives (1) a detailed study of the processing steps and their effect on physical properties so to be able to relate processing costs to product quality; (2) a continued study of electrical properties (3) a continued study of metallurgical reactivity and correlation with reactivity towards carbon dioxide and (4) production of a demonstration lot of synthetic coke using larger scale equipment.

2b. Coal Utilization

Under sponsorship of the Pacific Power and Light Company, research has continued along several lines directed at studying the properties of

the solid and liquid products derived from the coal used in the Dave Johnston plant at Glenrock. The financial support for this work has amounted to about $12,000. Most of the effort has been concerned with partially-devolatilized solid fraction of the coal with the view of utilizing the carbons either as-produced, or as-modified by further processing, for specialty carbons.

Some of the uses of carbon are related to the very extensive surface that becomes available upon carbonization of such coals. A grant by the Wyoming Natural Resource Board permitted the acquisition of gas chromatographic equipment which has been adapted to the measurement of surface areas. This is accomplished by procedures involving adsorption of nitrogen from nitrogen-helium gas mixtures at liquid nitrogen temperatures. The data obtained from such adsorption work is being correlated with carbon properties and can be used to describe the nature of the carbon surface.

2c. Coal Tar and Black Oil Utilization

With the continued support of the Wyoming Natural Resource Board the study of the processing of these heavy materials has gone forward. During the past year emphasis has been given to the problem of preventing crystallization and precipitation of asphaltenes and bitumens from these heavy liquids when they are heated. This precipitation was the source of much trouble in the valves, piping and vessels of the processing equipment resulting in flow stoppages. Furthermore, those solids which actually enter the reactors do not adsorb on the catalyst surfaces and hence are not attacked by the hydrogen but build up on the catalyst bed as inert diluent. Research has shown that the precipitation can be minimized by diluting the heavy oils with a naphthalene product and/or a heavy gas-oil fraction derived from the oil under study. This development will permit the resumption of work with the delayed coker and the hydrogenation units to develop general data which will define the amount and kind of dilution and/or recycle necessary to achieve uninterrupted operation.

The earlier work on hydrogenation was summarized in a paper "Petroleum and Coal Tar Research at the NRRI to 1961" by Ralph D. Law,

issued as NRRI Information Circular No. 22. This paper is to be distributed by the Wyoming Natural Resource Board.

2d. Miscellaneous Mineral Products

Work has continued on the study of the high temperature oxidation of cokes and chars by carbon dioxide as a measure of the reactivity of these materials. A paper by Edward Prostel and Neal Rice entitled "Reactivities of Western Subbituminous Coals and Their Chars" was presented at the September 1962 meeting of the American Chemical Society in Atlantic City, New Jersey. This paper is being revised to appear as an NRRI Information Circular.

The activity in this area has been extended taking in the entire range of coal ranks and carbonizing specimens at each of several, increasing temperatures. The carbon dioxide reactivity is being measured on each of the specimens. The work is nearing completion and will be prepared for publication.

A study was made of a number of clays from Converse County for the production of common brick. This work involved an evaluation of the way each clay must be handled in the forming, drying and firing of the brick. Some of the clays were shown to require very careful processing and the color of the fired brick was different from those on the market. Suggestions were made to overcome both of these difficulties.

A few samples of glass were prepared from glass sands from northern Big Horn County. The resulting glasses were a light greenish-blue and it was concluded that the sands would be satisfactory for the production of bottle glass in the as-received condition. No attempt was made to remove iron from the sand and thereby improve glass quality. This could be attempted if the market for clear glasses justified the cost.

Several samples of tar sand were studied, one quite extensively, with the view of effecting a mechanical separation of tar and sand. The results were not outstanding and additional work should be done on these materials to improve the separation.

Over the past several years the NRRI has received an increasing number of inquiries and coal samples in which the focus of interest has been the humic acid content. Related to this interest there has been an increase in the activity in the NRRI laboratories - and elsewhere - to learn more about these acids, their occurrence in Wyoming coals and something about their value in agriculture. Several lots of such materials have been made during the past year and some of these have been turned over to the Soil Section of the Plant Science Division of the College of Agriculture for pot testing. The first set of pot testing is almost done at this time and other groups of test are under way.

Some chemical work on the analysis of clays and the measurement of the ions present as exchangeable bases was undertaken. This work was set up with very active ion exchange resins and there appeared to be considerable attack of the clay mineral itself by the active resins. The work is being resumed with less active resins.

An extensive amalgamation study was made for a private sponsor.

2e. Test and Assay Services

In addition to handling the analyses generated by the research staff, the analytical laboratory ran over 2500 tests and analyses for fees for private individuals and companies during the year. This represents a considerable increase over the preceeding year. Income from this work amounted to about $5,500.

The nitron method for the determination of nitrogen in coals and carbonized materials has been further studied and the results have been shown to be in agreement with other methods which require more time and equipment.

3. WATER OPERATIONS

Research activities on better ways of surveying and utilizing Wyoming's water resources have grown substantially within NRRI during this year. Two water resources research engineers, Mr. Merlin C. Williams and Mr. George F. Dana, have been added to the full-time research staff for this work.

3a. Wyoming's Water Resource Data

The Wyoming Legislative Council sponsored the initial water resource activities within NRRI with a $7,000 contract to investigate and submit reports on:

- "A Bibliography of Wyoming's Water Resource Data" John C. Bellamy, Frank J. Trelease, III and Philip M. Hoyt, April 1962, 112 pages;
- "Periods of Records of Stream Gages in Wyoming, 1890-1961" Philip M. Hoyt and John C. Bellamy, August 1962, 8 pages and 1 map;
- "Report to the Wyoming Legislative Council on Wyoming's Water Resource Data" NRRI Staff, August 1962, 18 pages.

Briefly, these reports point out that needs for acquiring, interchanging and utilizing water resource data in Wyoming will surely increase markedly in the future. The extensive scope of such needs was clearly indicated by classifying them in terms of twelve major kinds of sequentially related data and data operations and in terms of the three (solid, liquid and gaseous) regions of the earth in which water resources occur. This classification provided a convenient and useful way of organizing the "Bibliography of Wyoming's Water Resources Data," and clearly indicated the need for greatly improved techniques and procedures for acquiring, processing and utilizing data in water operations. The report on "Periods of Records of Stream Gages in Wyoming, 1890-1961" utilized a newly developed "tallic" kind of number to present a great deal of numerical information in concise and readily useful form, and indicates that additional developments of newly possible "informatic" forms of data and equipment offer promising ways of solving many water operations data problems.

3b. Weather Modification Research

A $30,000 contract with the U. S. Bureau of Reclamation has supported a cooperative program of Weather Modification Research from February 12, 1962 through February 28, 1963, and is to be continued for three more years under a subsequent contract. Work under this initial contract is described in the following two reports.

(1) "Informatic Precipitation Gage Data" Merlin C. Williams and Leonard B. Baldwin, Jr., September 1962, 14 pages and 2 maps. NRRI Information Circular No. 18.

This report utilizes the same kind of "tallic" numerals developed for "Periods of Records of Stream Gages in Wyoming, 1890-1961" to provide conveniently useful portrayals of the periods of both hourly and daily precipitation gage records in Wyoming throughout the past. It also presents an initial attempt to utilize "tallic" forms of numerals to portray the hourly amounts of precipitation throughout the past. Although its particular illustrative example (of the amount of precipitation measured at Laramie each hour throughout a four year period) demonstrates the need for additional development, it strongly indicates that such additional developments could well result in exceptionally useful new ways of acquiring and utilizing meteorological and hydrologic data. Investigations of ways of adapting these new kinds of numerals to stream-flow and snow-course data are now underway and should be reported upon by September 1963.

(2) "Final Report (under Contract No. 14-06-D-4278) on Research in Ways of Modifying Weather to Increase Water Supply for Reclamation Projects in the State of Wyoming." NRRI Staff, March 1963, 25 pages.

Briefly, this initial year's weather modification research has resulted in:

- Furthering the development of "informatic" techniques of acquiring and utilizing data as discussed above;
- Recognition of the "cap clouds" which frequently occur during the winter over Wyoming's higher mountains as both an ideal subject for weather modification research and a possible potential source of artificially augmented snow pack and water supply;

- The establishment of a program of obtaining a photographic time-lapse census of the occurrences of clouds over the Medicine Bow Range, Elk Mountain, and the Wind River Range; and
- The recognition of Elk Mountain as a uniquely suitable site for additional detailed investigations of weather modification procedures in particular, and of Wyoming's kinds of water resources in general.

3c. Elk Mountain Water Resource Observatory

In view of the unique suitability of Elk Mountain for the purpose, an "Elk Mountain Water Resource Observatory" is now being established and operated by NRRI for research on ways of increasing and conserving water resources in Wyoming. This research will consist of observing and experimenting with natural and induced interchanges of moisture among the atmosphere, hydrosphere, lithosphere and biota cooperatively by many experimenters in the small but widely representative region of Elk Mountain. It will be performed by the staff and students of several of the Departments and Colleges of the University of Wyoming, together with personnel of other cooperating universities and governmental agencies. A brochure entitled "The Elk Mountain Water Resource Observatory" has been published by the staff of NRRI, and is now being used to enlist the cooperative participation of many other interested agencies.

4. AIR OPERATIONS

The NRRI program in Air Operations has consisted of the following activities.

4a. Support of Weather Modification Experiments

The College of Engineering's Twin Beech aircraft has been utilized this year primarily to support weather modification research. Reconnaissance flights of the Snowy Range and Elk Mountain regions are largely responsible for the recognition of the uniquely suitable character of Elk Mountain as a site for a water resource observatory. Aerial reconnaissance under contract with the South Dakota School of Mines and Technology also provided photographic records of the effects of their experimental seeding of convective clouds in the Rapid City area during August 1962. It is planned in the future to instrument this aircraft so that it can provide more quantitative information about atmospheric conditions before, during and after cloud seeding operations.

4b. Aeropilotage

All flights of the Twin Beech aircraft for whatever other purpose are also utilized to help develop techniques of "aeropilotage" or "flying with respect to charted features of the atmosphere." Their basic principles and advantages have been reported upon in "Principles of Aeropilotage" by Donald L. Veal, September 1962, 15 pages; this report has been preprinted as NRRI Information Circular 17 and has been accepted for publication in *Navigation*. The basic characteristics of aircraft instrumentation with which aeropilotage could become most useful have been described by John C. Bellamy in the Chapter on "Instrumentation for Aeropilotage" in "Air, Space and Instruments," Sydney Lees, Edictor; McGraw Hill, New York, New York, 1963.

4c. Aerodetic Units of Length

Air Operations research in NRRI is very closely related to the courses, CE 856FG AERODESY, which have been offered in the Civil Engineering Department, and which have been expanded for next year into CE 703D PRINCIPLES OF AERODESY, CE 870D OPERATIONAL ENGINEERING ANALYSIS, and CE 871D TOPICS IN

OPERATIONS ENGINEERING. While teaching the course in AERODESY this year, "Aerodetic Units of Length" were conceived and reported upon in "Proposed Aerodetic Units of Length" by John C. Bellamy (NRRI Information Circular No. 19, January 1963, 12 pages and accepted for publication in the *Journal of Applied Meteorology*), and in "Aerodetic Aspects of Altimetry" by John C. Bellamy (NRRI Information Ciruclar No. 20, February 1963, 21 pages and accepted for publication in *Navigation*).

Briefly, while considering better ways of determining and describing the shape and size of the level atmospheric surfaces (which is the subject matter of Aerodesy), it was recognized that a system of length units based upon the sexagesimal number system used to evaluate angles and time would be very advantageous. In essence they would then be based on the same rationale used originally to establish the meter, or metric unit of length; but they would correct for the error in judgement that decimal (rather than sexagesimal) numbers would come into use for evaluating angles and times. Specifically, the proposed units of length would consist of the common nautical mile, 60 nautical miles or a "nautical span", 1/60 of a nautical mile or a "nautical chain", and 1/6,000 of a nautical mile or a "nautical foot." Their international adoption could well eliminate the confusion and difficulties that the use of English and metric units of length now causes in, at least, aeronautical and meteorological operations.

5. SPACE OPERATIONS

NRRI's program in Space Operations is closely interrelated with its other operational engineering programs. For example, the weather satellites which will follow the TIROS and NIMBUS series offer great potentialities for improving the observation of such things as the extent of snow pack, storms and radiation upon which Wyoming's water supplies critically depend. Similarly flying through the atmosphere to and from space is the most critical aspect of space operations, and is in itself largely an air operations problem. Finally, the research, education and instrumentation industries associated with space operations are deemed to be especially desirable and appropriate for establishing a broad, strong base of industry in Wyoming.

5a. Space Science Summer Study

Most of this year's program in Space Operations consisted of the active participation of John C. Bellamy in the National Academy of Sciences - National Research Council's Space Science Summer Study from June 17 to August 10, 1962 at the State University of Iowa. This study was undertaken, in response to a request and supported by a grant from the National Aeronautics and Space Administration, to examine the current national program of basic research in space and its future objectives. As a result of participation in this study:

- The basic concepts of, and the great need for, a strong center of Operational Engineering research and education were evolved and implemented by the organization of NRRI toward that end;
- A proposal for a contract for conducting "Orbital Operational Studies" with emphasis on developing the potentialities of informatic techniques in NASA's tracking and data acquisition operations was prepared and has tentatively been approved for funding about September 1963; and
- Those operational and industrial needs of the nation's space effort which might best be supplied by Wyoming became more evident.

5b. Wyoming Space Age Industrial Workshop

These concepts concerning Wyoming's role in the space effort have been summarized in the paper "Growth Development of Education and Research in Relation to Industry in Wyoming" presented by John C. Bellamy at the Wyoming Space Age Industrial Workshop at Riverton, April 2, 1963 and published by the Wyoming Natural Resource Board together with the other papers presented on the Wyoming Space and Nuclear Age Day. Briefly this paper demonstrates that the "Research/Education Industry" is rapidly becoming one of the country's largest industries, that it is especially appropriate for development in Wyoming, and that the recent reorganization of NRRI has been toward this end.

5c. Wyoming's Orbital Airline Program

As a direct result of the contacts made by participation in the Wyoming Space Age Industrial Workshop in Riverton, and pursuant to permission granted in July 1962 by the Board of Trustees to establish (in effect) a "Department of Orbital Engineering," an Orbital Operations Engineering project has been established in NRRI to initiate an Orbital Airline Program in Wyoming. This program is based upon the convictions that:

- The keystone of sound explorations and exploitation of space is the economically profitable transportation of personnel and materiel to and from Space Stations with appropriately developed (orbital) transport aircraft;
- Such transportation can ultimately best be provided by private orbital airlines; and
- Fostering research and development by industry, state and federal government leading to private operations of orbital airlines is an important and proper function of State government.

The direct purposes of this Orbital Airlines project in NRRI are to:

- Establish the probable character and extent of future civil and military needs for orbital airline services;
- Establish the basic characteristics of orbital airline operations which will satisfy those needs;

- Help establish and coordinate corresponding research, development and operational programs and industries within the State and the United States; and
- Establish a curriculum of education in Orbital Operation Engineering at the University of Wyoming.

6. OPERATIONAL INSTRUMENTATION

The acquisition, processing and utilization of large amounts of numerical data is rapidly becoming the critical aspect of all kinds of operations with which natural resources are utilized. Consequently NRRI's research programs in all of mineral, water, air and space operations strongly involve research in improved kinds of data and associated equipments. Such data processing research is especially appropriate for NRRI sponsorship since it offers opportunities for research work toward Master's and Doctor's degrees in each of such diversified academic departments as Agricultural, Civil, Electrical, Mechanical and Petroleum Engineering. It also offers the possibility of developing new advanced kinds of instrumentation which, with proprietory rights and basic know-how, could well become the nucleus of a strong instrumentation manufacturing industry in Wyoming.

6a. Informatic Data Research

NRRI's instrumentation research efforts are centered largely on the development of newly possible "informatic" forms of data such as described previously in NRRI's publication "Informatic Forms of Data, 1961," and such as illustrated this last year in "Periods of Records of Stream Gages in Wyoming, 1890-1961" and "Informatic Precipitation Gage Data." Research on equipments with which to acquire and process such informatic forms of data consists largely of many individual projects by the staff and graduate students in Civil, Electrical and Mechanical Engineering. The following projects of this kind were worked on during the 1962-63 year.

(1) Tallic Typewriters:

The illustrative records in the reports on "Periods of Records of Stream Gages in Wyoming, 1890-1961" and "Informatic Precipitation Gage Data" were prepared by fitting a computer-output electric typewriter with appropriate keys for printing the tallic forms of numerals. These illustrations were typed manually at much larger than final size and photographically reduced for publication. A basic program for utilizing a Bendix G-15 Computer to reduce the amount of manual work required has been established as part of the graduate Electrical Engineering course,

EE 635M. A deck of IBM punch cards of hourly precipitation data in Wyoming is being prepared and edited to provide the data input for automatic typing of informatic portrayals of precipitation in the future.

(2) Electroscribing Recording:

Considerable effort has been expended during this year to develop recording techniques for reliably and simply producing tallic records at their ultimate small size with approximately 100 tallies per inch. An electroscribing technique has been selected in which a very small arc formed by passing an electric current through a pointed stylus vaporizes the portion to be marked of a thin aluminum coating on a mylar tape. Aluminized mylar has been selected as the recording material since the resultant record provides greater permanence and versatility of use than any other known kind of recording material. It is expected that a completely satisfactory recording technique of this kind will have been developed and reported upon by September 1963.

An electronic system for controlling such electroscribing has been developed by NRRI sponsored graduate research assistants in the Electrical Engineering Department. This control system is quite flexible, providing either for slow manual keyboard control or for rapid automatic control with signals from a Bendix G-15 computer.

(3) Electrographic Offset Printing:

One of the primary attributes of the electroscribed mylar kind of record is the possibility of utilizing it as an electrographic offset printing master. The basic techniques of this process were developed by Michael R. Rodda as described in his Electrical Engineering Master's Thesis, "Development of a Method of Printing a Desputtered Image from Aluminum-Coated Mylar Tape Using the Xerographic Process," August 1962. A project to prepare photographically reduced and etched metallic masters for electrographically printing small-size tallic records at appropriate positions on maps is also well advanced.

(4) Project SIPLOE

Project SIPLOE, standing for developing "Scaled Incremental Periodically Labelled Observing Equipment," was initiated in June 1963. The purpose of this project is to define, design and construct a prototype of inexpensive yet versatile equipment for observing the slowly varying occurrences of many variables at fixed hydrological and meteorological stations and in aircraft in support of aeropilotage procedures. Preliminary design considerations indicate that the utilization of informatic concepts and techniques might well result in obtaining exceptionally concise, useful and accurate numerical observations very inexpensively. It is planned that whatever equipment results from this project will be field-use tested in the Elk Mountain Water Resource Observatory.

6b. Instrumentation Research for the Ideal Aerosmith Company

A contract dated 29 March 1963 with the Ideal-Aerosmith Division of Royal Industries, Inc., Cheyenne, Wyoming is illustrative of the desired close working relationship between NRRI and Wyoming's instrumentation industries. Under the terms of this contract, staff and graduate students of the Electrical Engineering Department will work on a budget of $8,500 during the summer of 1963 upon projects which will improve and extend Ideal-Aerosmith's line of precision barometers, manometers, tilt-meters, control systems, etc. Research activities will be continued during the school year on an individual consulting basis, and Ideal-Aerosmith is generously providing the funds for a graduate research grant for the 1963-64 school year.

6c. Sensing Devices

NRRI's Informatic Data Research program is concerned primarily with the overall sequences with which numerical data is acquired by observation, collected, processed in many ways, and distributed to those who plan for the actual utilization of natural resources. The start of this entire chain of data-handling operations is the sensing of natural or controlled occurrences to provide analog signals for evaluation and recording as numberical observations. Since a different kind of sensor

is usually required for each different kind of occurrence to be observed, the development of appropriate sensors for various purposes provides an inexhaustible source of topics for work leading to Master's and Doctor's Theses.

Several sensor development projects of this type have been pursued this last year in the Electrical Engineering Department. One of them has resulted in a Master's Thesis "An Investigation of Squegging in Transistor Oscillators" by Irvin Dale Dunmire. Two closely associated projects are investigating "A Transponder for Long Range Telemetering of Signals from Miniaturized Sensors" and "A Miniaturized Multichannel Pulse Width, Frequency and Amplitude Modulator." In another project, the possibility of utilizing acoustic techniques to sense the average amount of soil moisture across quite large horizontal distances is being investigated.

The first three of these sensor research projects were motivated by the need to be able to implant miniature, low power drain, sensors in highway roadbeds or structures and in living organisms. It is expected that these interests in Highway Research and Medical Electronics in the Civil and Electrical Engineering Departments might well soon lead to the establishment of programs in Road Operations and Medical Operations within NRRI.

7. PERSONNEL

Since NRRI's organizational function is largely to provide graduate staff and students with research opportunities, its accomplishments can also be measured by the following list of personnel involved in and supported by its research programs.

EXECUTIVE COMMITTEE:

H. T. Person, Dean of Engineering, Chairman
G. D. Humphrey, President, Ex Officio
H. D. Thomas, State Geologist
R. A. Morgan, Assistant Dean of Engineering
A. J. McGaw, Head of Civil Engineering
J. C. Bellamy, Director of NRRI, Secretary

RESEARCH STAFF:

John C. Bellamy, Director
Walter E. Duncan, Assistant Director
Ralph D. Law, Petroleum Chemist
Edward Prostel, Coal Research Engineer
Neal Rice, Coal Research Chemist
Merlin C. Williams, Water Operations Engineer
George F. Dana, Water Research Engineer
Dan B. Field, Analytical Chemist

SUPPORT STAFF:

Oren F. Neal, Mechanic
Edwin F. Carlisle, Laboratory Technician
Thelma G. Hensen, Secretary
Karen L. Sturdevant, Typist (Resigned)
Lydetta K. Bailey, Typist (Part Time)

DIVIDED TIME (RESEARCH AND TEACHING) STAFF

		Summer 1962	1962-63 School Year	Summer 1963
Chesley W. Angle	Mechanical Engineer	X		
J. Earl Foster	Mechanical Engineer			X
R. Kenneth Beach	Electrical Engineer			X
Samuel D. Hakes	Electrical Engineer	X		X
Charles N. Rhodine	Electrical Engineer	X		X
A. L. Riemenschneider	Electrical Engineer			X
Leonard B. Baldwin, Jr.	Civil Engineer	X		
Robert L. Champlin	Civil Engineer	X		
Philip M. Hoyt	Civil Engineer	X		
Donald R. Lamb	Civil Engineer	X		
Donald L. Veal	Civil Engineer	X		X
Anton C. Munari	Hydrologist	X		X

GRADUATE RESEARCH ASSISTANTS

		Summer 1962	1962-63 School Year	Summer 1963
Richard D. Hanly	Mechanical Engineering	X		
Max T. Kershisnik	Mechanical Engineering	X		
Charles M. Myers	Mechanical Engineering		X	
Sylvan E. Brown	Electrical Engineering		X	
Norman M. Johnson	Electrical Engineering		X	
Rodney L. Kirlin	Electrical Engineering		X	
Robert W. Nagel	Electrical Engineering		X	
Michael K. Rodda	Electrical Engineering	X		
Victor A. Wells	Electrical Engineering		X	
Robert L. Williams	Electrical Engineering		X	X
Frank E. Farnham	Petroleum Engineering		X	
Francis P. Miknis	Physics	X		
Edward C. Endicott	Civil Engineering		X	
Everett H. Killam	Civil Engineering		X	
Verne E. Smith	Civil Engineering		X	

STUDENT LABORATORY ASSISTANTS

George H. Chamberlin
Rollin H. Denniston
John L. Dahlman
Robert N. Jones
Donald J. Engelbreck
Dennis M. Kiser
Robert W. Larson
George Miyake
James T. Moncur
Gandi R. Rajender
Tracy A. Rowland
John J. Smalley
James W. Stugart
Martin R. Tadlock, J
Marion E. VanZee
Edmund V. Waite

TECHNICAL ACTIVITIES AND PUBLICATIONS

This year's work of the research staff of NRRI has included the following notable technical activities:

John C. Bellamy

- American Meteorological Society
  - Member of Long Range Planning Commission
  - Member of Committee on Atmospheric Measurements
- Institute of Navigation
  - National President
- Associated Rocky Mountain Universities, Inc.
  - Executive Secretary of Committee for Nuclear Science and Technology
- National Academy of Science, Space Science Board
  - Participant in Space Science Summer (1962) Study

Walter E. Duncan

- American Institute of Mining, Metallurgical and Petroleum Engineers
  - Chairman of Wyoming Mining and Metals Section

Neal Rice

- American Society for Testing Materials
  - Member of Committee D-5 on Coal and Coke, assigned to
    - Subcommittee 18: Classification of Coals
    - Subcommittee 25: Physical Testing of Briquets
- International Briquetting Association
  - Secretary-Treasurer

PUBLICATIONS

Information Circulars:- Free

No. 15 Bellamy, John C., "Operational Engineering at the University of Wyoming," August 1962, 11 pp.

No. 16 Bellamy, John C. and Philip M. Hoyt, "Periods of Records of Stream Gages in Wyoming, 1890-1961," August 1962, 8 pp. and map.

No. 17 Veal, Donald L., "Principles of Aeropilotage," September 1962, 15 pp.

No. 18 Williams, Merlin C. and Leonard B. Baldwin, Jr., "Informatic Precipitation Gage Data," September 1962, 14 pp. and 2 maps.

No. 19 Bellamy, John C., "Proposed Aerodetic Units of Length," January 1963, 12 pp.

No. 20 Bellamy, John C., "Aerodetic Aspects of Altimetry," February 1963, 21 pp.

No. 21 Bellamy, John C. and Staff, "Weather Modification Research," March 1963, 25 pp. Report to the U. S. Bureau of Reclamation on Contract No. 14-06-D-4278.

No. 22 Law, Ralph D., "Petroleum and Coal Tar Research at the NRRI to 1961," April 1963, 34 pp.

Papers:

"Reactivities of Western Subbituminous Coals and Their Chars," by Edward Prostel and Neal Rice. Presented at Atlantic City meeting of American Chemical Society, September 1962.

"The Natural Resources Research Institute, Its Objectives and Program," by Walter E. Duncan. Presented at Assessor's School, Laramie, October 1962.

"Instrumentation For Aeropilotage," by John C. Bellamy, Chapter in *Air, Space and Instruments*, Sydney Lees, Editor; McGraw Hill, New York, New York, 1963.

"Growth Development in Education and Research in Relation to Industry in Wyoming," by John C. Bellamy. Presented to Wyoming Space Age Industrial Workshop at Riverton, April 1963.

Theses:

"Development of a Method of Printing a Desputtered Image from Aluminum-coated Mylar Tape Using the Xerographic Process," by Michael R. Rodda, Master of Science in Electrical Engineering, August 1962.

"The Application of Informatic Data Forms to Precipitation Records," by Merlin C. Williams, Master of Science in Civil Engineering, August 1962.

Reports:

To Wyoming Legislative Council:

"A Bibliography of Wyoming's Water Resource Data," by John C. Bellamy, F. J. Trelease,III, and Philip M. Hoyt, April 1962, 112 pp.

"Periods of Records of Stream Gages in Wyoming, 1890-1961," by Philip M. Hoyt and John C. Bellamy, August 1962, 8 pp. and 1 map.

"Wyoming's Water Resource Data," NRRI Staff, August 1962, 18 pp.

To Union Pacific Railroad Foundation:

"Synthetic Coke Project: Final Report of 1961-62 Project," by Walter E. Duncan, Edward Prostel and Neal Rice, July 1962.

"Synthetic Coke Project: First Quarterly Report of 1963 Project," by Walter E. Duncan, Edward Prostel and Neal Rice, April 1963.

To University of Wyoming Board of Trustees:

"Progress in Establishing a Program of Orbital Engineering," by John C. Bellamy, September 1962.

To Wyoming Natural Resource Board:

"Testing of Lovell Glass Sand," by Walter E. Duncan, November 1962.

"Testing of Douglas Clays," by Walter E. Duncan, January 1963.

"Memorandum on Surface Area Measurement," by Walter E. Duncan, February 1963.

Reports: (Cont.)

To U. S. Bureau of Reclamation on Contract No. 14-06-D-4278

Quarterly Letter Progress Reports dated:
September 1962
December 1962

"Weather Modification Research," Final Report by John C. Bellamy and Staff, March 1963, 25 pp.

To Pacific Power and Light Company:

Several Progress Reports by Walter E. Duncan, Edward Prostel and Neal Rice dated:
August 1962
November 1962
January 1963
April 1963

Several smaller private reports on miscellaneous activities.

333.7
W98
1963/65

Progress Report

July 1963 to June 1965

NATURAL RESOURCES RESEARCH INSTITUTE

JAN 06 1966
Library

College of Engineering
University of Wyoming
Laramie, Wyoming

Twentieth and Twenty-First Annual Reports

PREFACE

The Natural Resources Research Institute, or NRRI, was established in 1943 and reorganized in 1949 as the Engineering Experiment Station of the University of Wyoming. Since 1961 it has beeen functioning, in effect, as the Organized Research Department of the College of Engineering.

The primary purposes of NRRI are to promote Wyoming's economic growth through research on ways of utilizing our natural resources, and to provide the staff and graduate students of the University with opportunities for such research. This research is accomplished by the full time staff of NRRI with its laboratory and field facilities, as well as by the academic staff and graduate students of the several Colleges of the University as an integral part of its expanding program of graduate education.

Most of NRRI's research projects are performed in cooperation with other state, federal and private agencies. They are supported by state appropriations and by grants and contracts with governmental agencies, corporations and individuals. In addition, NRRI's laboratory facilities and staff are available, at cost, for materials testing and assay services.

NRRI's activities are organized with respect to the material and transportation aspects of the four basic (land, water, air and space) kinds of natural resources. Its projects are concerned primarily with the end-use or operational engineering aspects of their utilization, including especially ways of acquiring, processing and utilizing information about all kinds of natural resources.

NRRI's water resource activities include serving as the administrative unit of the University-wide Wyoming Water Resources Research Institute.

THE UNIVERSITY OF WYOMING
COLLEGE OF ENGINEERING

NATURAL RESOURCES RESEARCH INSTITUTE
P. O. BOX 3038, UNIVERSITY STATION
LARAMIE, WYOMING 82071

PROGRESS REPORT: JULY 1963 - JUNE 1965

BRIEF

Section | Page

1. SCOPE: This report describes the activities of NRRI during the period from July 1, 1963 through June 6, 1965 in each of the six general kinds of natural resources research with respect to which the following research projects have been organized and are discussed. 1

2. MINERALS RESEARCH 3
    2.1 Synthetic Coke 3
    2.2 Coal Hydrogenation 4
    2.3 Coal Utilization 5
    2.4 Lignite Creosote 5
    2.5 Glass Sands 6
    2.6 Test and Assay Services 6

3. HIGHWAY RESEARCH 7
    3.1 Highway Failure Pilot Study 7
    3.2 Roadway Failure Study 8

4. WATER OPERATIONS RESEARCH 10
    4.1 Water Resource Operations Study 12
    4.2 Watershed Treatment Study 14

5. ATMOSPHERIC WATER RESOURCES RESEARCH 15
    5.1 Weather Modification Research 15
    5.2 Informatic Data Research, Precipitation Gage Data 17

6. AIR OPERATIONS RESEARCH 18

7. SPACE OPERATIONS RESEARCH 19
    7.1 Orbital Operations Study 19

8. SUMMARY. The expanding level of NRRI activities is summarized with lists of its personnel and of their other professional activities. 21

THE UNIVERSITY OF WYOMING
COLLEGE OF ENGINEERING

NATURAL RESOURCES RESEARCH INSTITUTE
P. O. BOX 3038, UNIVERSITY STATION
LARAMIE, WYOMING 82071

PROGRESS REPORT: JULY 1963 - JUNE 1965

1. SCOPE

This report describes the activities of the Natural Resources Research Institute during the period from July 1, 1963 to June 6, 1965. This nearly two year period encompasses the periods which, in accordance with previous practice, would have been reported upon with the Twentieth and Twenty-First Annual Reports for the periods July 1, 1963 - June 30, 1964 and July 1, 1964 - June 30, 1965.

This change in reporting practice reflects a major change in the pattern of NRRI's activities. Heretofore most of its research was conducted by its full time research staff and tended to be least active during the mid-summer vacation period. Now, however, an ever increasing fraction of its research is being conducted by the staff and graduate students of academic departments of the University part-time during the school year and at a greatly accelerated full-time tempo during the three summer months. Consequently mid-summer is now the period of greatest activity for the full-time and summer staff alike, and the first of July now occurs at the middle instead of at the end of the effective "research year."

It is therefore planned to report hereafter on NRRI's activities for the yearly periods which begin and end with Commencement each spring. This reporting schedule will provide for: preparing the annual reports during the period of greatest teaching but least research activity; reporting upon the intense summertime activities as an undivided whole; and utilizing the annual reports to help plan for the intensive research work of the forthcoming summer.

The level of activity in NRRI has also increased markedly during this reporting period as a direct tangible result of an expansion in 1961 of the scope of its interests to include all kinds of natural resources. That expansion has been organized in terms of the source-of-material and environment-for-transportation aspects of the natural resources of each of the land, water, air and space. Of these eight basic kinds of natural resources research, active research projects have been established for the following six classes, numbered in accordance with the Sections of this report in which they are discussed.

2. Minerals Research
   (Source-of-materials of the land)

3. Highway Research
   (Environment-for-transportation on the land)

4. Water Operations Research
   (Source-of-materials of the water)

5. Atmospheric Water Resources Research
   (Source-of-materials of the air)

6. Air Operations Research
   (Environment-for-transportation in the air)

7. Space Operations Research
   (Environment-for-transportation in space).

2. MINERALS RESEARCH

Research on ways of utilizing the mineral resources of the land continued as a major interest of NRRI at an unabated level throughout this reporting period. The untimely death of Dr. Ralph D. Law in January 1964 came as a blow to the hydrogenation aspects of the Institute's work and especially, to those of us who had been working closely with him since he joined the staff of the Institute in 1952. His position was filled in April 1964 by Dr. Howard F. Silver as a Chemical Engineer with assignments in both NRRI and the Department of Petroleum and Chemical Engineering.

2.1 Synthetic Coke

Purpose: To find ways of producing synthetic coke from Wyoming's non-coking coals.
Sponsor: Union Pacific Railroad Foundation
Support: $18,700 in FY 1964; $10,000 in FY 1965
Status: Initiated in 1960; Completed May 1964
Facilities: NRRI Laboratories
Carbonizing plant and briquetting press in Chicago
Publications: Interim reports July, Nov. 1963; Jan. 1964.

Final Report "Synthetic Coke from Non-Coking Coal"
Edward Prostel, Neal Rice, Walter E. Duncan;
NRRI Information Circular No. 34, May 1964, 7 pp.
(Presented at Spring Field Meeting of Coal Division,
Society of Mining Engineers, AIME, May 1965.
Submitted for publication by AIME)
Principal Investigators: Walter E. Duncan, Edward Prostel, Neal Rice.

Previous work on this project has demonstrated that artificial coke can be produced from a wide range of coals with greater carbon dioxide reactivity and comparable phosphate reactivity and physical strength in comparison with fused cokes. During this reporting period good coke was produced from an extended range of coals from bituminous C through several subbituminous coals, including a sample of lignite. In addition, a demonstration lot of more than a quarter-ton of coke was successfully produced

with commercially available briquetting equipment in Chicago and with NRRI's gas-fired heat treating oven. This concluding use-test of our studies of production and testing procedures demonstrated their applicability to at least a pilot-plant scale of production, and helped to establish those variations of procedures and costs with which artificial cokes having particular specified properties can be produced.

2.2 Coal Hydrogenation

Purpose: To find ways of producing bituminous highway construction materials by hydrogenation of Wyoming coals.
Sponsor: Wyoming Highway Department in association with the U. S. Bureau of Public Roads.
Support: $45,250
Status: Initiated June 1, 1964; Renewed June 1965.
Facilities: NRRI Laboratories
Petroleum Engineering Laboratories
Publications: Monthly and quarterly reports,
Final Report, June 1965.
Principal Investigators: Howard F. Silver, Burl E. Davis
Walter E. Duncan.

The goal of this project is to establish hydrogenation procedures which will convert as large a percentage of coal as possible into a heavy bituminous cement, rather than into the more common lighter oil and gaseous products of coal hydrogenation. It has been found that a major portion of Wyoming subbituminous coals can be converted into a heavy bituminous product, the physical properties of which are now being determined with emphasis on determining its viscous behavior in comparison with common asphalts and road tars. It is planned to process and test this product as a bituminous cement, and soon to publish the results of an extensive literature survey which was completed during this time period.

2.3 Coal Utilization

Purpose: To study the properties of the coal, carbons and fly ash from the Dave Johnston Plant at Glenrock.
Sponsor: Pacific Power and Light Company
Support: $14,642
Status: Continuing
Facilities: NRRI and Civil Engineering Laboratories
Publications: Interim reports of July, November and December 1963, February and June 1964
Principal Investigators: Neal Rice, Edward Prostel, Walter E. Duncan, Burl E. Davis.

This project is concerned with evaluating this particular kind of coal and the partially devolatilized carbon derived from it in terms of specialty carbon products with very extensive surface areas. In addition the fly ash from this coal is being evaluated for possible use as a pozzolanic material.

2.4 Lignite Creosote

Purpose: To determine the value of lignite creosote as a wood preservative.
Sponsor: Husky-Dominion Briquets
Support: $8,347
Status: Initiated August 1964, Completed June 1965
Facilities: NRRI and Veterinary Science Laboratories
Publications: Interim Reports: December 1964 and March 1965
Final Report: June 1965
Principal Investigator: Edward Prostel.

The goal of this project is to compare the fungicidal and aging properties of the liquid by-products of low temperature carbonization of lignite with those of the usual creosote derived from high temperature coking of coal. These tests, based largely on a recently developed wood block test of fungicidal properties in comparison with pentachlorophenol, have indicated that the lignite creosote has considerable merit as a wood preservative. It is planned to describe this work in detail in a forthcoming paper.

2.5 Glass Sand

Purpose: To study methods of preparing low-iron sand for the production of glass
Sponsor: Wyoming Natural Resource Board
Support: $1,200
Status: Initiated February 1965, Continuing
Facilities: NRRI Laboratories
Publications: None
Principal Investigators: Walter E. Duncan, Burl E. Davis, Robert L. Wise

A sandstone from near Lovell, Wyoming is being tested to determine the extent of deleterious iron content in the ranges of particle sizes used in glass making. Tests of the economic feasibilities of abrasive washing and chemical leaching to reduce its iron content are now being conducted.

2.6 Test and Assay Services

Purpose: To provide the residents of Wyoming and others with NRRI's facilities for a wide variety of analyses and evaluations of materials.
Sponsors: Individuals and Corporations
Support: $7,589 for the period July 1963 - June 1965
Status: Continuing
Facilities: NRRI and Civil Engineering Laboratories
Publications: Individual reports of test results
Principal Investigators: Staff

These services range from free identifications of mineral and rock samples for many tourists and prospectors to detailed quantitative at-cost analyses of materials with probable commercial value for, especially, companies which wish to supplement and check their own laboratory work.

[illegible]

[illegible]: [illegible] R. [illegible], [illegible] E. [illegible]

A [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

2. [illegible]

[illegible] [illegible] [illegible] materials.

[illegible]

[illegible] of materials with [illegible] [illegible]

3. HIGHWAY RESEARCH

The initiation of an active program of Highway Research in NRRI during this period is a prime example of the enlarged scope of NRRI's activities. This program is directed by Dr. Donald R. Lamb, the Head of the Civil Engineering Department, and is closely integrated with the academic program of that department.

3.1 Highway Failure Pilot Study

Purpose: To determine the causes of roadway failures and to find preventive or remedial measures for Wyoming highways near, in particular, Lance Creek and Wamsutter.
Sponsor: Wyoming Highway Department and the U. S. Bureau of Public Road
Support: $57,535
Status: Initiated Sept. 1, 1963; Terminated Dec. 31, 1964
Facilities: Civil Engineering Materials Laboratory
NRRI Laboratories
Transportation to Field Sites
Highway Department Drill Truck
Publications: Monthly Progress Reports
Final Report: "Roadway Pilot Failure Study"
December 1964, 163 pp.
Principal Investigators: Donald R. Lamb, Raymond D. Pavlovich, William G. Scott.

The Lance Creek phase of this study was concerned with roadway failures by undulation, rutting and severe pavement cracking. These failures were all found to be attributable to the montmorillonite soil on which the road was constructed. This kind of soil changes volume with changes of moisture content, thereby producing undulations and rutting which result in severe alligator or map cracking. The search for remedial or preventive measures demonstrated that the swelling of this kind of soil can be controlled by using hydrated lime as a stabilizing agent, but that the complete elimination of upheaval would require the development of an economical means of introducing the

stabilizing agent into the subgrade without physically reworking the entire soil mass. Consequently the control of subgrade moisture by draining borrow areas, by sealing cracks in the asphaltic concrete, and by emplacing an impermeable membrane on the top of the subgrade, has been recommended for highway construction wherever the Pierre Shale is the subgrade material.

The Wamsutter phase of this study was concerned with lateral and longitudinal cracking, some alligator or map cracking, rutting, and some post construction consolidation of the median areas. The post construction consolidation was found to result from insufficient consolidation during construction and a subsequent impoundment of water in the median area. Some of the other failures are attributable in part to the use of too soft or too much sealer material. The major cause of failure was found, however, to be the loss of supporting strength of the basement layers of the system into which water had intruded, apparently through lateral cracks in the asphaltic concrete. Additional research is needed to determine the causal sequence of events and, especially, the mechanisms whereby lateral cracks can form prior to structural failure of basement or subgrade layers.

3.2 Roadway Failure Study

Purpose: To continue investigations of the causes of roadway distress from expansive clays and pavement cracking and of preventive or remedial measures.
Sponsor: Wyoming Highway Department and the U. S. Bureau of Public Roads.
Support: $87,900
Status: Initiated December 1, 1964; To be terminated August 31, 1966
Facilities: Civil Engineering Materials Laboratory
NRRI Laboratories
Transportation to Field Sites
Highway Department Drill Truck
Publications: Quarterly progress reports
Principal Investigators: Donald R. Lamb, Raymond D. Pavlovich
William G. Scott, Robert Gietz,
Eugene W. Stettler

This study is a continuation of the preceding study. The causal sequences of events associated with the wetting of expansive clay basement layers are being studied by collecting samples from many sites for laboratory analysis and by utilizing neutron probes to monitor in-situ changes of soil moisture. The causes and effects of lateral cracking of asphaltic concretes are being studied primarily in the laboratory, with emphasis on the determination of the physical properties of asphaltic concretes under, especially, extreme changes of temperature.

4. WATER OPERATIONS RESEARCH

NRRI activities with regard to water resources were greatly expanded during this reporting period by, especially, establishing the Wyoming Water Resources Research Institute as a University-wide organization administered as a major subdivision of the Natural Resources Research Institute. Its activities are governed by the following Water Resources Research Panel, each of the members of which represent the water resources research interests in one of the eight colleges of the University.

Agriculture	- Oscar K. Barnes
Arts and Sciences	- George T. Baxter
Commerce and Industry	- Floyd K. Harmston
Education	- Glenn S. Jensen
Engineering	- Paul A. Rechard
Law	- Joseph R. Geraud
Nursing	- Helen M. Huebert
Pharmacy	- Lola V. Hopkins

The Director of NRRI serves as the Executive Secretary of this Panel. In addition, the following Associate Members of the Panel have been appointed from each of the executive agencies of the State of Wyoming with major water resource interests.

Attorney General	- John Raper
State Engineer	- Floyd Bishop
State Geologist	- William H. Wilson
Highway Department	- Mainard Wacker
Public Health Department	- Arthur Williamson
State Board of Agriculture	- O. Henry Engendorff
Game and Fish Commission	- Ted Baker
Land Commission	- Carl Johnson
Natural Resource Board	- Myron Goodson
Parks Commission	- Harold Odde

This organization has been established as that explicit means whereby the University of Wyoming can best:

(1) Foster and interrelate competent research on all important aspects of water resources throughout the university;

(2) Utilize existing facilities such as offices, laboratories and equipments throughout the University as required for the Institute's activities;

(3) Provide for participation in the activities of the Institute by highly qualified and motivated staff members and graduate students of any or all Departments of the University; and

(4) Help support the activities of the Institute with those many other kinds of funds which are required to establish and maintain the facilities and permanent staff of a competent and effective State University.

This University-wide kind of organization in explicit association with State-wide water resource agencies has also been established as being the most effective means of:

(1) Utilizing the multitude of professional, coordinative and contractual contacts of personnel throughout the University to interrelate the University's program and projects with those of the large number of Federal, State and private agencies engaged in water resources research;

(2) Utilizing existing staff competencies throughout the University as a broad directive base for research by recent graduates and trainees in order to maximize the training of young scientists, as well as to minimize the displacement of scientists from existing programs of water resources research elsewhere;

(3) Expanding the base of direct personal contact with State and local officials, organizations and individuals concerning all aspects of water resource supplies, needs, administration and use;

(4) Providing those communication channels whereby whatever kind of advice and assistance might be provided by the Director of the national Office of Water Resources Research can be transmitted directly to those in the University who could best utilize it; and

(5) Ensuring the ready contractual or other administrative availability of whatever combination of disciplines might need to become involved in coordinated programs or projects with other institutes or agencies.

The Water Resources Research Institute thus bears two kinds of relationships with water resources research, education and service in the University of Wyoming. First, in an overall informative sense, its activities encompass all water-resource-related activities within the University. Second, in a much narrower funding and directive sense, the "work of the Institute" refers to only those activities in the University which are supported directly by funds allocated to the Institute. Those funds are typified by allotments under the Water Resources Research Act of 1964, and will not support more than a small fraction of the overall water resources research within the several Departments and Colleges of the University.

4.1 Water Resource Operations Study

Purpose: To learn more about the relationships among the many kinds and aspects of Water Resource Operations.
Sponsor: Office of Water Resources Research, U. S. Department of the Interior
Support: $52,297.29 for FY 1965
Status: Initiated in May 1965, to continue indefinitely
Facilities: Offices and Laboratories of the University,
Elk Mountain Water Resources Observatory
Publications: Initial mimeographed description of the "Water Resources Research Study."
Principal Investigators: Staff of Six Colleges of the University

This project has been established as that single multidisciplinary, University-wide, water resources research project whereby the WyoWRRI can best serve the purposes of Wyoming's yearly allotments authorized by the Water Resources Research Act of 1964 (PL 88-379). Purpose and substance has been provided by establishing as initial objectives the determination of:

(1) Criteria for Water Resource Planning
by studying the basic problems relating to
"Trans-Basin Diversions in Wyoming"
with a study team headed by
- Oscar K. Barnes, Special Projects Leader in Extension, College of Agriculture,
- Floyd K. Harmston, Director, Division of Business and Economic Research, College of Commerce and Industry,
- Joseph R. Geraud, Director, Wyoming Land and Water Law Research Center, College of Law,
- Paul A. Rechard, Water Resources Research Engineer, Natural Resources Research Institute, College of Engineering,
- John T. Thompson, Water Administration Specialist, Political Science Department, College of Arts and Sciences,
- Orland W. Ward, Chairman, Department of Health, Physical Education and Recreation, College of Education;

(2) Bio-Physical Relationships in the Hydrologic Cycle
by implementing the
"Multiple Use of the Elk Mountain Water Resources Observatory"
under the coordinated direction of
- Archie Reid, Specialist in Water Relations of Plants, Botany Department, College of Arts and Sciences,
- D. L. Blackstone, Chairman, Geology Department, College of Arts and Sciences,
- Richard W. Weeks, Instrumentation Research Engineer, Natural Resources Research Institute, College of Engineering,
- L. R. Painter, Specialist on Agricultural Effects on Water Quality, Soils Section, College of Agriculture,
- Clarence F. Becker, Head of the Department of Agricultural Engineering, Colleges of Agriculture and of Engineering, and
- George T. Baxter, Specialist in Limnology and Fisheries Management, Zoology and Physiology Department, College of Arts and Sciences;

(3) The Impact of Weather Modification
with a joint legal and engineering investigation of
"Artificial Snow Pack Augmentation"
with co-principal investigators
- Frank J. Trelease, Dean of the College of Law and
- Merlin C. Williams, Weather Modification Project Engineer, NRRI, College of Engineering; and

(4) Principles of Analysis of Water Resource Operations
by utilizing the data and experience of the other detailed aspects of the study coordinated by
- John C. Bellamy, Director of NRRI, College of Engineering.

This project could be little more than organized during the one month of its existence during this reporting period. Nevertheless very good progress was made during this month toward effectively utilizing the FY'65 funds (before July 1965) to acquire about $43,000 worth of observational equipment for use in conjunction with the Elk Mountain Water Resource Observatory. These observational equipments will greatly assist the development of this uniquely suitable area on and around Elk Mountain for many interrelated kinds of field studies of many basic aspects of water resources.

4.2 Watershed Treatment Study

Purpose: To evaluate ways of treating subalpine water sheds in Wyoming to increase water supplies.
Sponsor: Wyoming Natural Resource Board
NRRI
Support: $1,500 from WNRB
Status: Initiated Sept. 1964, to be completed August 1965
Facilities: NRRI Offices
Automobile and Aircraft Field Transportation
Publications: "A Watershed Treatment Technique for Subalpine Runoff" (To be published August 1965)
Principal Investigators: Everett H. Killam, Merlin C. Williams.

This project was concerned specifically with those watershed treatments which might be applicable to the Big Sandy, Little Sandy and Pacific Creek headwaters of the Eden Reclamation Project in Western Wyoming, with primary emphasis on selected timber removal and the use of snowfences to increase snow pack. An extensive literature survey was performed at the outset, followed by aerial and ground reconnaissance of the areas of interest and conferences with United States Forest Service personnel in Kemmerer, Wyoming and Fort Collins, Colorado. This work indicates that it is very desirable to strip-cut the timber in this headwaters area from both a forest cultivation and snow-pack augmentation point of view, but that the use of snow fences in this region is not desirable at this time. It is estimated that between about 4,500 and 6,700 additional acre-feet (or an increase of between about 15 and 23 percent) of runoff could be achieved with proper strip-cutting of the timber in this area.

5. ATMOSPHERIC WATER RESOURCES RESEARCH

The "source-of-material aspects of the natural resources of the atmosphere" are being studied within NRRI primarily as they related to the atmosphere as being virtually the sole source of water in Wyoming. As indicated below, this kind of activity has increased greatly during this reporting period.

5.1 Weather Modification Research

Purpose: To establish sound engineering principles of increasing water supplies by seeding Wyoming's wintertime cap-clouds.
Sponsor: U. S. Bureau of Reclamation
Support: March 1963 - November 1964, $107,000
November 1964 - June 1965, $141,000
Status: Originated February 1962, continuing.
Facilities: NRRI Offices and Laboratories
Elk Mountain Water Resources Observatory
Brees Field Facility
Automobiles, Over-Snow Vehicles, NRRI Aircraft
USBR Radars.
Publications: Summary Report: "Weather Modification Research" NRRI Information Circular No. 26, April 1964, 21 pp.

"Weather Modification, University of Wyoming" Merlin C. Williams, Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers, January 1965, Vol, 91, Hyl, pp. 93-104.
Principal Investigators: Merlin C. Williams, John C. Bellamy, George F. Dana, Everett H. Killam, Robert L. Williams, Donald L. Veal, Dennis J. Knowlton, Richard W. Weeks.

This project has expanded rapidly during this reporting period in order to capitalize upon the discovery in the 1962-63 winter season (1) that the cap-clouds which frequently enshroud Wyoming's high mountain peaks in the wintertime are a significant potential source of additional snow-pack and (2) that Elk Mountain some 50 miles to the northwest of the campus in Laramie is

a uniquely suitable site for engineering research on ways of utilizing this newly discovered source of water. The art of seeding such cap-clouds with silver iodide was advanced during the 1963-64 and 1964-65 winter seasons to the point that NRRI's experienced field personnel can now turn the fall of snow on and off from virtually any desired portion of Elk Mountain's cap-clouds virtually at will. A preliminary attempt to translate this seeding art to the Wind River mountains during February 1965 was rendered unsuccessful by the occurrence of natural storms instead of cap clouds throughout the period of time available for the experiment. This experience in the massive Wind River mountains did very usefully prove, however, the great utility of the ready accessibility to and all around Elk Mountain for this kind of field research.

The primary research effort of this project is now to transform this seeding art into a more quantitative science for ultimate use in the larger headwater areas of Wyoming. Toward this end, an intensive instrumentation of the Elk Mountain Water Resource Observatory was initiated by the installation of six snow-pillow sites and four wind sites during the fall of 1964, and the quantitative data obtained with these instruments during the 1964-65 winter season is now being analyzed. This work has clearly demonstrated the need to develop and utilize much more intensive and extensive observing facilities. Toward this end: a radar and instrumentation test and rehabilitation facility is being established on Brees Field; an improved photo-reconnaissance capability has been provided in the NRRI aircraft; three over-snow vehicles and three four-wheel drive vehicles have been acquired; a first step toward an "informatic" observing, collecting and recording system is to be developed during the summer of 1965 for first experimental use test on Elk Mountain the next winter; and plans and arrangements are in progress for constructing an Observing Post on the top of Elk Mountain so that detailed quantitative observations of the effects of seeding can be determined from within the cap-cloud itself.

5.2 Informatic Data Research, Precipitation Gage Data

Purpose: To develop a more useful "informatic" form of data for compiling hourly precipitation data.

Sponsors: U.S. Weather Bureau, U.S. Bureau of Reclamation, NASA, NRRI

Support: U.S. Weather Bureau, $2,000

Status: Initiated July 1964, to be completed August 1965

Facilities: NRRI Laboratories
University of Wyoming Computing Center

Publications: "Status of Informatic Data Research, 1963" John C. Bellamy, NRRI Information Circular No. 23, August 1963, 13 pp.

"Data Display for Analysis" John C. Bellamy
Symposium for Environmental Measurements
U.S. Public Health Service, July 1, 1964, pp. 213-226.

"'SIPLIC' Forms of Hourly Precipitation Data"
Anton C. Munari, John C. Bellamy; NRRI Information Circular No. 32 (To be published August 1965).

Principal Investigators: Anton C. Munari, John C. Bellamy, Merlin C. Williams.

This project is part of an overall program of Informatic Data Research of NRRI being sponsored in part internally and in part by the Weather Bureau, the Bureau of Reclamation and NASA. The specific goal of this particular project is to help solve the data storage and retrieval problems of the Weather Bureau's National Weather Records Center with explicit attention to hourly precipitation data. The major portion of the detailed work sponsored by the Weather Bureau consisted of programming an IBM 1620 computer to convert punched-card stores of hourly precipitation data for thirteen years at each of Casper, Cheyenne, Lander and Sheridan into a "SIPLIC" form of data on but one 8-1/2 by 11 inch page of paper for each station. The "SIPLIC" or "Scaled Incremental, Periodically Labelled, Incrementally Continuous" form of informatic data has been demonstrated by this work to be readily capable of automatic compilation, to provide a very good overall view of the pattern of times and amounts of precipitation, and to provide an extremely concise store of complete numerical precipitation data for direct use by both man and, potentially, appropriately developed machines.

6. AIR OPERATIONS RESEARCH

Work in NRRI on the environment-for-transportation-within-the-atmosphere aspect of natural resources was at a relatively low, internally sponsored, level during this reporting period. Its primary emphasis is on the development of operational procedures of "aeropilotage", or of "flying with respect to charted features of the atmosphere." The following three articles in this field were published near the beginning of this period.

"Proposed Aerodetic Units of Length" John C. Bellamy
Journal of Applied Meteorology Vol. 2 No. 3, August 1963.

"Aerodetic Aspects of Altimetry" John C. Bellamy
Navigation Vol. 10, No. 2 pp. 119-128, Summer 1963.

"Principles of Aeropilotage" Donald L. Veal
Navigation Vol. 10, No. 2 pp. 129-135, Summer 1963.

As indicated by the first of these titles, the most difficult problem to be solved before aeropilotage can become operationally useful is that of the units of length to be used to chart the distribution of occurrences throughout the atmosphere. Continued attention is being given to this units problem, and promising indications of a logical and practicable solution have been obtained during the latter part of this reporting period.

7. SPACE OPERATIONS RESEARCH

The natural resources of space are being studied in NRRI from an environment-for-transportation point of view, with primary attention on the potentialities of the transport-in-orbit of instruments and facilities to help observe (and to provide for the communication of) complete space-time distributions of occurrences on the land and sea and throughout the atmosphere. Several contemporary unmanned satellites are intended for this specific purpose and others are intended to obtain the knowledge of the space environment required for manned operations in space. Both of these kinds of activities are of direct interest to NRRI since the ultimate realization of the full potentialities of observing the Earth from space evidently depends upon the establishment of several kinds of manned orbital observing and communication stations.

7.1 Orbital Operations Study

Purpose: To help establish more productively effective ways of controlling orbital operations by, especially, investigating the potentialities of Informatic Forms of Data for such operations.

Sponsor: National Aeronautics and Space Administration, Grant No. NsG 658

Support: May 1964, $83,000; May 1965, $50,000

Status: Initiated May 1964, continuing

Facilities: NRRI Laboratories,
Special Data Recording Equipment from NASA

Publications: Semi-annual progress reports, Nov. 1964, May 1965;

"Plan of Study, Orbital Operations Study" John C. Bellamy, NRRI Information Circular No. 27, August 1964, 30 pp;

"Proposed Nautical Units of Length and Time" John C. Bellamy, NRRI Information Circular No. 28, April 1965, 20 pp, (To be published in Navigation).

Principal Investigators: John C. Bellamy, Willis J. Everett, Dennis Kiser, Dennis Knowlton, Richard W. Weeks, R. Kenneth Beach, Richard J. Jiacoletti, Charles N. Rhodine, A. L. Riemenschneider, Donald L. Veal.

This project is a good example of the newer kind of interdisciplinary projects with which NRRI is providing opportunities for research to the academic staff and graduate students of the University. For example, five of the graduate research assistants for this project during this period were from the Department of Electrical Engineering, two were from the Department of Physics and one each were from the Departments of Mathematics, Civil Engineering and Mechanical Engineering. Of the staff participating in this project, five were teachers in Electrical Engineering, two in each of Civil and Mechanical Engineering and one in Physics.

The initial study tasks in this project are: to formulate illustrative examples of informatic forms of scientific, engineering and positional data from satellites; to fabricate experimental data recorders for informatic forms of data; to design and construct experimental electronic buffers for use between general purpose computers and those informatic recording devices; and to initiate the definition of the elements of orbital operations and of their interrelationships as, especially, they might be affected by the use of informatic forms of data.

Very satisfactory progress was made during this first year of this study. Several advances in ways of analyzing large scale operations such as this were incorporated in the "Plan of Study" report, and the "Proposed Nautical Units of Length and Time" offer good promise of helping to solve the difficult units problem for orbital operations. The construction of suitable recorders and computer buffers has been found to be more difficult than originally expected, thereby delaying somewhat the formulation of illustrative examples of informatic forms of orbital data. It is expected, however, that at least five more technical reports will be published as a result of this work in the fall of 1965.

8. SUMMARY

As indicated by the foregoing discussion, the level of activity in NRRI has increased greatly during this reporting period. This pattern of growth is clearly reflected in the following table of budgets for the last five fiscal years.

Fiscal Year	State Appropriations	Grants and Contracts	Total
1960-61	$62,000	$ 39,000	$101,000
1961-62	64,000	53,000	117,000
1962-63	66,000	96,000	162,000
1963-64	75,000	167,000	242,000
1964-65	88,000	410,000	498,000

This growth pattern is also clearly reflected in the following list of NRRI's personnel and of the professional activities in which they engaged during this period in addition to those which have already been discussed.

FULL TIME STAFF

Director: John C. Bellamy
(Professor of Civil Engineering)
Member, Board of Certified Consulting Meteorologists, American Meteorological Society, 1963-65
Member, Instrumentation Committee, American Meteorological Society
Executive Secretary, Nuclear Education Committee, Associated Rocky Mountain Universities, 1963-65
Member, Flight Facility Advisory Panel, National Center for Atmospheric Research, 1963
Participant, Weather Modification Research Panel, American Society of Civil Engineers, March 1964
Speaker, Symposium on Environmental Measurements, U.S. Public Health Service, Cincinnati, Ohio, July 1964
Governor's Representative, U.S. Department of Commerce State Science and Technology Conferences, 1964 and 1965,
Participant, Space Age Conferences, 1964 and 1965, Riverton, Wyoming
Co-sponsor, State Registration Law for Weather Modification, 1965
Secretary, Accelerator Committee of Wyoming; Principal Author of "Characteristics of the Site in Wyoming for the National Accelerator Laboratory" submitted in June 1965 to the Atomic Energy Commission.

Assistant Director: Walter E. Duncan
Executive Board, Wyoming Mining and Metals Section, AIME
Member, Gordon Research Conference on Coal Science, New Hampton, New Hampshire, 1963
Member, American Conference on Coal Science, Pennsylvania State University, 1964
Speaker, Spring Meeting of Coal Division, Society of Mining Engineers, AIME, 1965

Highway Research Engineer: Donald R. Lamb
(Head of Department of Civil Engineering)
Chairman: Nuclear Principles and Applications Committee, Special Committee No. 8, Highway Research Board, National Academy of Science.
Member: Aggregate Committee, Highway Research Board, National Academy of Science
Member: Panel No. 10, National Cooperative Highway Research Panel
Member: Education Committee, American Road Builders Association
President: Bellamy Chapter, National Society of Professional Engineers
Director: Civil Engineering Division, American Society for Engineering Education
Chairman: Educational Guidance for Wyoming, Engineering Council for Professional Development.

Water Research Engineer: Paul A. Rechard
(Started September 1964; Professor of Civil Engineering)
Published "Determining Bank Storage of Lake Mead" Journal of the Irrigation and Drainage Division of ASCE, Vol. 91 No. IR1, March 1965, pp. 141-157.
Speaker, "Water Resources Research at the University of Wyoming," Sigma Xi and numerous luncheon clubs.
Co-sponsor, State Registration Law for Weather Modification, 1965.

Orbital Research Engineer: Willis J. Everett
(Started September 1964; Associate Professor in Electrical Engineering)
Member, Nuclear Education Committee, Associated Rocky Mountain Universities
Speaker, Numerous seminars on Nuclear Engineering and Characteristics of the Ionosphere.

Coal Research Engineer: Edward Prostel
Participant, 8th International Briquetting Conference, Denver, Colorado, August 1963
Speaker, Spring Meeting of Coal Division, Society of Mining Engineers, AIME, 1965.

Coal Research Chemist: Neal Rice
Secretary and Editor, International Briquetting Association, 1963-65
Chairman, 8th International Briquetting Conference, Denver, Colorado, August 1963
Representative, D-5 Coal Committee, American Society for Testing Materials
Speaker, Spring Meeting Coal Division, Society of Mining Engineers, AIME 1965.

Petroleum Research Chemist: Ralph D. Law
(Deceased, January 1964)

Chemical Research Engineer: Howard F. Silver
(Started April 1964)
Taught Petroleum Engineering

Atmospheric Water Research Engineer: Merlin C. Williams
Taught Civil Engineering
Participant, N.S.F. Weather Modification Workshop, Yellowstone Park, 1964 and 1965.
Speaker, Weather Control Research Association Meeting, Reno, Nevada, April 1964
Member, Precipitation Committee, Hydrology Section, American Geophysical Union
Became a Registered Professional Engineer in Wyoming, 1965
Co-sponsor, State Registration Law for Weather Modification, 1965
Speaker at numerous local meetings to describe the Elk Mountain snow-pack augmentation work.

Water Research Geologist: George F. Dana

Instrumentation Research Engineers:
Dennis Kiser (Started September 1964, taught in Mechanical Engineering)
Dennis J. Knowlton (Started September 1964, taught in Electrical Engineering
Richard W. Weeks (Started May 1965)

Analytical Chemists:
Daniel B. Field (Resigned September 1963)
Burl E. Davis (Started September 1963, Received B.A. June 1965)

Research Associates:
William G. Scott (Highways, Instructor of Civil Engineering)
Raymond D. Pavlovich (Highways)
Robert Gietz (Highways, Started May 1965)
Eugene V. Stettler (Highways, Started February 1965)
Everett H. Killam (Water, received M.S. in C.E., June 1965,
Thesis: "A Watershed Management Technique for Increasing Subalpine Runoff";
Participant, Snow Measurement Workshop, Soil Conservation Service, Portland, Oregon, July 1964)
Robert L. Williams (Radar Weather, received M.S. in E.E., June 1965,
Thesis: "A Reflector Comparison Method for Calibrating Weather Radars"

Technicians:

Edwin R. Carlisle	(Chemical, Resigned December 1963)
George H. Chamberlin	(Electronic, Started September 1963)
James L. Colling	(Chemical, Resigned December 1964)
Howard F. Guill	(Mechanical, Started September 1964)
Calvin M. Holz	(Electronic, Started October 1964)
Erik A. Johnson	(Field, Started January 1965)
Darrell E. Labrenz	(Electronic with E.E. & M.E. Depts.)
Oren F. Neal	(Mechanic, Resigned June 1965)
Roger D. Ramsey	(Electronic, Started January 1965)
Howard Roberts	(Machinist with M.E. Dept.)
Raymond K. Tremain	(Chemical, Resigned June 1964)
Robert L. Wise	(Chemical, Started February 1965)

Office Staff:
Thelma Hensen (Secretary)
Beth Yoss (Clerk, Started September 1964)
Geraldine Eisenhauer (Clerk, Started January 1965)
Ellen J. Chelesvig (Typist, Resigned September 1963)
Elaine Hannaback (Typist, Resigned February 1964)
Barbara C. Berry (Typist, Resigned April 1964)
Judy C. Conyers (Typist, Resigned September 1964)
Lenobelle M. LaDick (Typist, Resigned December 1964)

SUMMER FACULTY STAFF, 1963

Robert C. Champlin	(Instructor of Civil Engineering)
J. Earl Foster	(Associate Professor of Mechanical Engineering)
Samuel D. Hakes	(Associate Professor of Electrical Engineering)
Anton C. Munari	(Assistant Professor of General Engineering)
Charles N. Rhodine	(Assistant Professor of Electrical Engineering)
A. L. Riemenschneider	(Instructor of Electrical Engineering)
Donald L. Veal	(Instructor of Civil Engineering)

SUMMER FACULTY STAFF, 1964

R. Kenneth Beach	(Professor of Electrical Engineering)
Richard J. Jiacoletti	(Assistant Professor of Mechanical Engineering)
Anton C. Munari	(Assistant Professor General Engineering)
Charles N. Rhodine	(Assistant Professor of Electrical Engineering)
A. L. Riemenschneider	(Instructor of Electrical Engineering)
Donald L. Stinson	(Head of Department of Petroleum Engineering)
Donald L. Veal	(Assistant Professor of Civil Engineering)

GRADUATE RESEARCH ASSISTANTS:	Summer 1963	1963 1964	Summer 1964	1964 1965
Civil Engineering				
Larry A. Baccari				X
Johan Dahl				X
James O. Duguid	X	X		
Nick J. Kanellopoulos		X	X	
Everett H. Killam		X	X	
Electrical Engineering				
David K. Bement		X		
Laurence L. Bement		X		
Lothar H. Bullinga				X
Havyn E. Bradley				X
Jim W. Cady			X	X
Maurice Clary		X		
Harry R. Devereaux			X	
Dennis J. Knowlton			X	
Ronald A. Stahla			X	X
James Stugart				X
Marion E. Van Zee	X	X		
Robert L. Williams	X	X	X	
Mathematics				
David Fjeld				X
Mechanical Engineering				
Lt. Rudolph J. Arnold				X
Dennis Kiser	X		X	
Petroleum Engineering				
John Angelovich				X
Jerry M. Calkins				X
Dan J. Likwartz				X
Evart E. Mulholland				X
Physics				
Roland Lamberson				X
Thomas Ensign				X

PART TIME STUDENT ASSISTANTS, 1963-1964

Bret R. Allard
John M. Angelovich
Adnan M. Bakkar
Lydetta K. Bailey
Lindley M. Bowman
Michael P. Brown
Jerry Calkins
William W. Clark
Roger L. Costello
Mark A. Hoffman
Edward C. Johnson
Daniel D. Kadel
Robert W. Larson
Carl E. Lindberg
James A. Mickelson
George Miyake
James T. Moncur
Clifford E. Moore
Gandi R. Rajender
Tracy A. Rowland
Donald C. Slack
John J. Smalley
Steven E. Swaldi
Martin R. Tadlock, Jr.
Per Christian Vedeler
Edmund V. Waite

PART TIME STUDENT ASSISTANTS, 1964-1965

Peteris R. Ans
Ronald L. Atkins
Adnan M. Bakkar
Lydetta K. Bailey
Doran K. Boston
Howard H. Bashford
Wayne T. Beddes
Gary W. Birdsall
Douglas C. Campbell
Robert L. Carpenter
Paul D. Driscoll
Franklin G. Doolittle
Donald J. Engelbrecht
John C. Fernau
Donald F. Greywood
Mark A. Hoffman
Douglas F. Hollingshead
Jarrell R. Hagan
Harold Infanger
Daniel D. Kadel
Robert D. Kruse
Robert W. Larson
George E. Lessley
Carl E. Lindberg
Jay E. Lyon
George Miyake
James T. Moncur
Larry C. Offe
Carl W. Rapp
Peter K. Schakel
Donald C. Slack
John J. Smalley
Eugene W. Stettler
Stephen E. Swaldi
Dennis J. Stanford
Ronald C. Turtle
David R. Timmins
Martin R. Tadlock, Jr.
Per Christian Vedeler